Martin O'Malley
Governor

Anthony G. Brown
Lieutenant Governor

Robert M. Summers, Ph.D
Secretary

August 26, 2013

Mr. Jon Capacasa, Director
Watershed Protection Division
U.S. Environmental Protection Agency Region III
1650 Arch Street
Philadelphia, PA 19103-2029

Dear Mr. Capacasa:

In accordance with the Memorandum of Understanding between the U.S. Environmental Protection Agency (EPA) and the Maryland Department of the Environment (MDE), and consistent with Section 303(d) of the Clean Water Act, please find enclosed for your review and approval:

- Documentation for the Water Quality Analysis (WQA) of Chromium in Northwest Branch and Bear Creek Portions of the Patapsco River Mesohaline Tidal Chesapeake Bay Segment, Baltimore City and Baltimore County, Maryland;

- A comment response document which records the Department's responses to public comments on the referenced WQA documentation: three sets of written comments were received;

- Copies of the original comments received during the public review period.

MDE appreciates the time your staff has spent regarding this project, and we are confident that EPA will be able to concur with the WQA. If you need any of the documents cited in the reference list, other supporting materials, or have clarifying questions, please contact Mr. Tony Allred of my staff at (410) 537-3582.

Sincerely,

D. Lee Currey, Director
Science Services Administration

Enclosures

Maria Garcia, Watershed Protection Division, U.S. EPA Region III, w/encl.
Robert M. Summers, PhD, Secretary, Maryland Department of the Environment
Paul De Santis, Office of the Attorney General, Maryland Department of the Environment, w/encl.
Matthew Rowe, Deputy Director, Science Services Administration, Maryland Department of the Environment
Dinorah Dalmasy, Acting Program Manager, Science Services Administration, Maryland Department of the Environment
John Backus, Acting Program Manager, Science Services Administration, Maryland Department of the Environment
File w/encl.

Water Quality Analysis of Chromium in Northwest Branch and Bear Creek Portions of the Patapsco River Mesohaline Tidal Chesapeake Bay Segment, Baltimore City and Baltimore County, Maryland

DRAFT - FINAL

MARYLAND
DEPARTMENT OF THE ENVIRONMENT
1800 Washington Boulevard, Suite 540
Baltimore MD 21230-1718

Submitted to:

Watershed Protection Division
U.S. Environmental Protection Agency, Region III
1650 Arch Street
Philadelphia, PA 19103-2029

July 2013

Submittal Date:
Approval Date:

AVS	Acid Volatile Sulfides
BIBI	Benthic Index of Biotic Integrity
BOD	Biological Oxygen Demand
BSM	Spatial Mapping of Sedimentary Contaminants in the Baltimore Harbor
CBF	Chesapeake Bay Foundation
CBL	Chesapeake Biological Laboratory
CFR	Code of Federal Regulations
COMAR	Code of Maryland Regulations
COPR	Chrome Ore Processing Residue
Cr	Chromium
Cr (III)	Trivalent Chromium
Cr (VI)	Hexavalent Chromium
CTFR	Center for Contaminant Transport, Fate, and Remediation
CWA	Clean Water Act
DMT	Dundalk Marine Terminal
DO	Dissolved Oxygen
EPA	US Environmental Protection Agency
ERA	Ecological Risk Assessment
ERM	Effects Range Median
Fe	Iron
Fe (II)	Divalent (Ferrous) Iron
FIBI	Fish Index of Biotic Integrity
JHU	Johns Hopkins University
LOAEL	Lowest Observed Apparent Effects Level
MDE	Maryland Department of the Environment
mg/kg	Milligrams per Kilogram
Mn	Manganese
Mn (II)	Divalent Manganese
Mn (III)	Trivalent Manganese
Mn (IV)	Tetravalent Manganese
ND	Non-detect
PAH	Polyaromatic Hydrocarbon
PATMH	Patapsco River Mesohaline
Pb	Lead
PCB	Polychlorinated Biphenyl
PBDE	Polybrominated Diphenyl Ether
PEL	Probable Effects Level
ppt	Parts per Thousand
SCS	Soil Conservation Service
SEM	Simultaneously Extracted Metals
SHA	State Highways Administration
SQG	Sediment Quality Guideline
SQT	Sediment Quality Triad

UM	University of Maryland
UMCES	University of Maryland Center for Environmental Sciences
µmole/g	Micromole/gram
USDA	United States Department of Agriculture
USGS	United States Geological Survey
WQA	Water Quality Analysis
WQLS	Water Quality Limited Segment
WREC	Wye Research and Education Center
Zn	Zinc
µg/L	Micrograms per Liter

This document, upon approval by the U.S. Environmental Protection Agency (EPA), presents a Water Quality Analysis (WQA) of chromium (Cr) in the Northwest Branch and Bear Creek (Maryland 8-Digit basin number: 02130903) portion of the Patapsco River Mesohaline (PATMH) Tidal Chesapeake Bay Segment (2012 *Integrated Report of Surface Water Quality in Maryland* Assessment Unit ID: MD-PATMH-NORTHWEST_BRANCH / MD-PATMH-BEAR_CREEK). Section 303(d) of the federal Clean Water Act (CWA) and the EPA's implementing regulations direct each State to identify and list waters, known as water quality limited segments (WQLSs), in which current required controls of a specified substance are inadequate to achieve water quality standards. For each WQLS listed on the *Integrated Report of Surface Water Quality in Maryland* (Integrated Report), the State is to either establish a Total Maximum Daily Load (TMDL) of the specified substance that the waterbody can receive without violating water quality standards, or demonstrate via a WQA that water quality standards are being met (CFR 2012).

Maryland's Surface Water Use Designations in the Code of Maryland Regulations (COMAR) state that all surface waters of Maryland shall be protected for water contact recreation, fishing, and the protection of aquatic life and wildlife (COMAR 2012a). In addition, the specific designated use of the Northwest Branch and Bear Creek portions of PATMH is Use II (*Support of Estuarine and Marine Aquatic Life and Shellfish Harvesting*) (COMAR 2012b,c).

The Maryland Department of the Environment (MDE) has identified the PATMH Tidal Chesapeake Bay Segment (Integrated Report Assessment Unit ID: PATMH) on the State's 2012 Integrated Report as impaired by nutrients – nitrogen and phosphorus (1996), sediments – total suspended solids (1996), and impacts to biological communities (2004). The Baltimore Harbor portion of the PATMH Tidal Chesapeake Bay Segment has been individually identified on the 2012 Integrated Report as impaired by chlordane (1996) and polychlorinated biphenyls (PCBs) (1998) (MDE 2012b). The Middle Branch (Ferry Bar Park to Harbor Hospital Center extending westward) and the Northwest Branch (Hull Street Pier to Canton Waterfront Park) portions of the PATMH Tidal Chesapeake Bay Segment have been individually identified on the 2012 Integrated Report as impaired by trash (2008) (MDE 2012b). The Northwest Branch portion of the PATMH Tidal Chesapeake Bay Segment has been individually identified on the 2012 Integrated Report as impaired by chromium in sediments (1998), lead (Pb) in sediments (1998), zinc (Zn) in sediments (1998), and enterococcus (2010) (MDE 2012b). The Bear Creek portion of the PATMH Tidal Chesapeake Bay Segment has been individually identified on the 2012 Integrated Report as impaired by chromium in sediments (1998), Zn in sediments (1998), and PCBs (1998) (MDE 2012b). The Integrated Report specifies that the chromium impairments in the Northwest Branch and Bear Creek portions of the PATMH Tidal Chesapeake Bay Segment do not support the protection of aquatic life designated use of the waterbodies. From this point forward in the report, the Baltimore Harbor, Northwest Branch, and Bear Creek portions of the PATMH Tidal Chesapeake Bay Segment will simply be referred to as Baltimore Harbor, Northwest Branch, and Bear Creek.

The WQA presented herein by MDE will address the 1998 chromium listings for Northwest Branch and Bear Creek, for which a data solicitation has been conducted, and all readily

approved by the EPA on December 29, 2010, has also addressed the nutrient listings for the PATMH Tidal Chesapeake Bay Segment and is currently under reevaluation to determine whether previously developed TMDLs would be superseded by the corresponding Bay TMDL. The sediment listing for the PATMH Tidal Chesapeake Bay Segment has also been addressed via the Chesapeake Bay TMDL. The trash listings for the Middle Branch and Northwest Branch portions of the PATMH Tidal Chesapeake Bay Segment are being addressed through a TMDL currently under development and planned for submittal to EPA in 2013. The listing for impacts to biological communities in the PATMH Tidal Chesapeake Bay Segment will be addressed separately at a future date. The listing for chlordane in Baltimore Harbor has been addressed through a TMDL approved by EPA on March 23, 2001. The listings for PCBs in Bear Creek and Baltimore Harbor have been addressed through a TMDL submitted to EPA on September 30, 2011. The listings for Pb, Zn, and enteroccocus in the Northwest Branch and Zn in Bear Creek will be addressed separately at a future date.

The original 1998 listings for chromium in the sediments of Northwest Branch and Bear Creek from Maryland's Integrated Report were established using the Sediment Quality Triad (SQT) approach, the designated methodology for assessing waters of the State for toxic impairments in sediment as Maryland has no numeric sediment quality criterion for chromium (MDE 2012a). Water quality data demonstrated that sediment toxicity and a degraded benthic community were present within the Northwest Branch and Bear Creek and sediment concentrations for total chromium exceeded the sediment quality guideline (SQG) Effects Range Median (ERM). These findings indicated that the sediment was impaired for chromium. In retrospect this approach was methodologically flawed as a comparison of total chromium sediment concentrations and the ERM for total chromium did not take into consideration the relative toxicity associated with the speciation of Cr (III) and Cr (VI). The Cr (VI) species is highly toxic while the Cr (III) species is relatively non-toxic at levels typically found within the environment.

MDE submitted a WQA to EPA in August 20, 2004, presenting newly collected water quality data at the time that demonstrated chromium was not a source of toxicity to aquatic life inhabiting the water column or sediment. The sediments of the Northwest Branch and Bear Creek support a reducing environment which facilitates the conversion of Cr (VI) to Cr (III). Therefore under these conditions Cr (III), the relatively non-toxic species, will be the predominant form of chromium within the sediments. EPA supported the findings of this WQA through a delayed approval, contingent upon the results of a toxicity, identification, and evaluation (TIE) study underway at the time. The results of the TIE study were inconclusive; therefore, chromium was not delisted and remained in Category 5 of Maryland's Integrated Report.

This document presents the findings of recent studies completed by Johns Hopkins University (JHU), an Ecological Risk Assessment (ERA) of Dundalk Marine Terminal (DMT) and an EPA Data Evaluation of Bear Creek sediments which all support the conclusions of the original WQA that toxicity in the sediments of Baltimore Harbor is not due to the presence of chromium. Therefore, a TMDL for chromium is not necessary to achieve water quality standards supportive of the protection of aquatic life designated use in Northwest Branch and Bear Creek.

("waterbody is impaired, does not attain the water quality standard, and a TMDL is required") to Category 2 ("waterbodies meeting some [in this case chromium related] water quality standards, but with insufficient data to assess all impairment") when MDE proposes revision of the State's Integrated Report. Although the tidal waters of Northwest Branch and Bear Creek do not display signs of a chromium impairment to aquatic life in the water column or sediment, the State reserves the right to require future controls if evidence suggests that chromium from the watershed is contributing to downstream water quality problems.

This document, upon approval by the U.S. Environmental Protection Agency (EPA), presents a Water Quality Analysis (WQA) of chromium (Cr) in the Northwest Branch and Bear Creek (Maryland 8-Digit basin number: 02130903) portions of the Patapsco River Mesohaline (PATMH) Tidal Chesapeake Bay Segment (2012 *Integrated Report of Surface Water Quality in Maryland* Assessment Unit ID: MD-PATMH-NORTHWEST_BRANCH / BEAR CREEK). Section 303(d) of the federal Clean Water Act (CWA) and the EPA's implementing regulations direct each State to identify and list waters, known as water quality limited segments (WQLSs), in which current required controls of a specified substance are inadequate to achieve water quality standards. For each WQLS listed on the *Integrated Report of Surface Water Quality in Maryland* (Integrated Report), the State is to either establish a Total Maximum Daily Load (TMDL) of the specified substance that the waterbody can receive without violating water quality standards, or demonstrate via a WQA that water quality standards are being met (CFR 2012).

A segment identified as a WQLS may not require the development and implementation of a TMDL if more recent information invalidates previous findings. The most common scenarios that would eliminate the need for a TMDL are: 1) analysis of more recent data indicating that the impairment no longer exists (i.e., water quality standards are being met); 2) results of a more recent and updated water quality model demonstrate that the segment is now attaining water quality standards; 3) refinements to water quality standards or to the interpretation of those standards accompanied by analysis demonstrating that the standards are being met; or 4) identification and correction of errors made in the initial listing. This document presents a WQA that eliminates the need for a TMDL for chromium in the Northwest Branch and Bear Creek portions of the Patapsco River Mesohaline Chesapeake Bay Segment (PATMH) incorporating the third scenario stated above.

Maryland's Surface Water Use Designations in the Code of Maryland Regulations (COMAR) state that all surface waters of Maryland shall be protected for water contact recreation, fishing, and the protection of aquatic life and wildlife (COMAR 2012a). In addition, the specific designated use of the Northwest Branch and Bear Creek portions of the PATMH Tidal Chesapeake Bay Segment is Use II (*Support of Estuarine and Marine Aquatic Life and Shellfish Harvesting*) (COMAR 2012b,c).

The Maryland Department of the Environment (MDE) has identified the PATMH Tidal Chesapeake Bay Segment (Integrated Report Assessment Unit ID: PATMH) on the State's 2012 Integrated Report as impaired by nutrients – nitrogen and phosphorus (1996), sediments – total suspended solids (1996), and impacts to biological communities (2004). The Baltimore Harbor portion of the PATMH Tidal Chesapeake Bay Segment has been individually identified on the 2012 Integrated Report as impaired by chlordane (1996) and polychlorinated biphenyls (PCBs) (1998) (MDE 2012b). The Middle Branch (Ferry Bar Park to Harbor Hospital Center extending westward) and the Northwest Branch (Hull Street Pier to Canton Waterfront Park) portions of the PATMH Tidal Chesapeake Bay Segment have been individually identified on the 2012 Integrated Report as impaired by trash (2008) (MDE 2012b). The Northwest Branch portion of the PATMH Tidal Chesapeake Bay Segment has been individually identified on the 2012

of the PATMH Tidal Chesapeake Bay Segment has been individually identified on the 2012 Integrated Report as impaired by chromium in sediments (1998), Zn in sediments (1998), and PCBs (1998) (MDE 2012b). The Integrated Report specifies that the chromium impairments in the Northwest Branch and Bear Creek portions of the PATMH Tidal Chesapeake Bay Segment do not support the protection of aquatic life designated use of the waterbodies. From this point forward in the report, the Baltimore Harbor, Northwest Branch, and Bear Creek portions of the PATMH Tidal Chesapeake Bay Segment will simply be referred to as Baltimore Harbor, Northwest Branch, and Bear Creek.

The WQA presented herein by MDE will address the 1998 chromium listings for Northwest Branch and Bear Creek, for which a data solicitation has been conducted, and all readily available data from the past five years has been considered. The nutrient listings for the PATMH Tidal Chesapeake Bay Segment and Baltimore Harbor have been addressed through a TMDL approved by EPA on December 17, 2007. The Chesapeake Bay TMDL, which was approved by the EPA on December 29, 2010, has also addressed the nutrient listings for the PATMH Tidal Chesapeake Bay Segment and is currently under reevaluation to determine whether previously developed TMDLs would be superseded by the corresponding Bay TMDL. The sediment listing for the PATMH Tidal Chesapeake Bay Segment has also been addressed via the Chesapeake Bay TMDL. The trash listings for the Middle Branch and Northwest Branch portions of the PATMH Tidal Chesapeake Bay Segment are being addressed through a TMDL currently under development and planned for submittal to EPA in 2013. The listing for impacts to biological communities in the PATMH Tidal Chesapeake Bay Segment will be addressed separately at a future date. The listing for chlordane in Baltimore Harbor has been addressed through a TMDL approved by EPA on March 23, 2001. The listings for PCBs in Bear Creek and Baltimore Harbor have been addressed through a TMDL submitted to EPA on September 30, 2011. The listings for Pb, Zn, and enteroccocus in the Northwest Branch and Zn in Bear Creek will be addressed separately at a future date.

The original 1998 listings for chromium in the sediments of Northwest Branch and Bear Creek from Maryland's Integrated Report were established using the Sediment Quality Triad (SQT) approach, the designated methodology for assessing waters of the State for toxic impairments in sediment as Maryland has no numeric sediment quality criterion for chromium (MDE 2012a). Water quality data demonstrated that sediment toxicity and a degraded benthic community were present within the Northwest Branch and Bear Creek and sediment concentrations for total chromium exceeded the sediment quality guideline (SQG) Effects Range Median (ERM). These findings indicated that the sediment was impaired for chromium. This approach was methodologically flawed as a comparison of total chromium sediment concentrations and the ERM for total chromium did not take into consideration the relative toxicity associated with the speciation of Cr (III) and Cr (VI). The Cr (VI) species is highly toxic while the Cr (III) species is relatively non-toxic at levels typically found within the environment.

MDE submitted a WQA to EPA in August 20, 2004, presenting newly collected water quality data at the time that demonstrated chromium is not a source of toxicity to aquatic life inhabiting the water column and sediment. The sediments of the Northwest Branch and Bear Creek support

chromium within the sediments. EPA supported the findings of this WQA through delayed approval of the delisting, contingent upon the results of a stressor identification study underway at the time. The results of the study were inconclusive; therefore, chromium was not delisted and remains in Category 5 of Maryland's Integrated Report.

This document presents the findings of recent studies completed by Johns Hopkins University (JHU), an Ecological Risk Assessment (ERA) of Dundalk Marine Terminal (DMT) and an EPA Data Evaluation of Bear Creek sediments which all support the conclusions of the original WQA that toxicity in the sediments of Baltimore Harbor is not due to the presence of chromium. Therefore, a TMDL for chromium is not necessary to achieve water quality standards supportive of the protection of aquatic life designated use in Northwest Branch and Bear Creek. The WQA supports the removal of the chromium impairment listings for Northwest Branch and Bear Creek, when MDE proposes the revision of the State's Integrated Report.

The remainder of this report includes the general setting of the Northwest Branch and Bear Creek watershed, background information on chromium chemistry and chromium sources within the Baltimore Harbor, a review of previous MDE studies addressing the chromium listings in Northwest Branch and Bear Creek, a review of the JHU studies, ERA of DMT, and EPA Data Evaluation of Bear Creek sediments investigating the toxicity of chromium in Baltimore Harbor sediments and conclusions regarding an evaluation of these studies.

2.0 GENERAL SETTING

The Northwest Branch and Bear Creek are located within the Baltimore Harbor. The Northwest Branch watershed (embayment plus drainage area) covers 43,046 acres and include the Jones Falls watershed, which flows into the Northwest Embayment. The Bear Creek watershed (embayment plus drainage area) covers 7,460 acres. The locations of the Northwest Branch and Bear Creek embayments are displayed in Figure 2.1 and 2.2, respectively.

There are no "high quality," or Tier II, stream segments (Benthic Index of Biotic Integrity (BIBI) and Fish Index of Biotic Integrity (FIBI) aquatic life assessment scores > 4 (scale 1-5)) located within the embayment's watershed requiring the implementation of Maryland's anti-degradation policy (COMAR 2012d; MDE 2011). The total population in the Northwest Branch and Jones Falls watershed is approximately 176,198 and 368,879, respectively. The total population in the Bear Creek watershed is approximately 57,414 (US Census Bureau 2010).

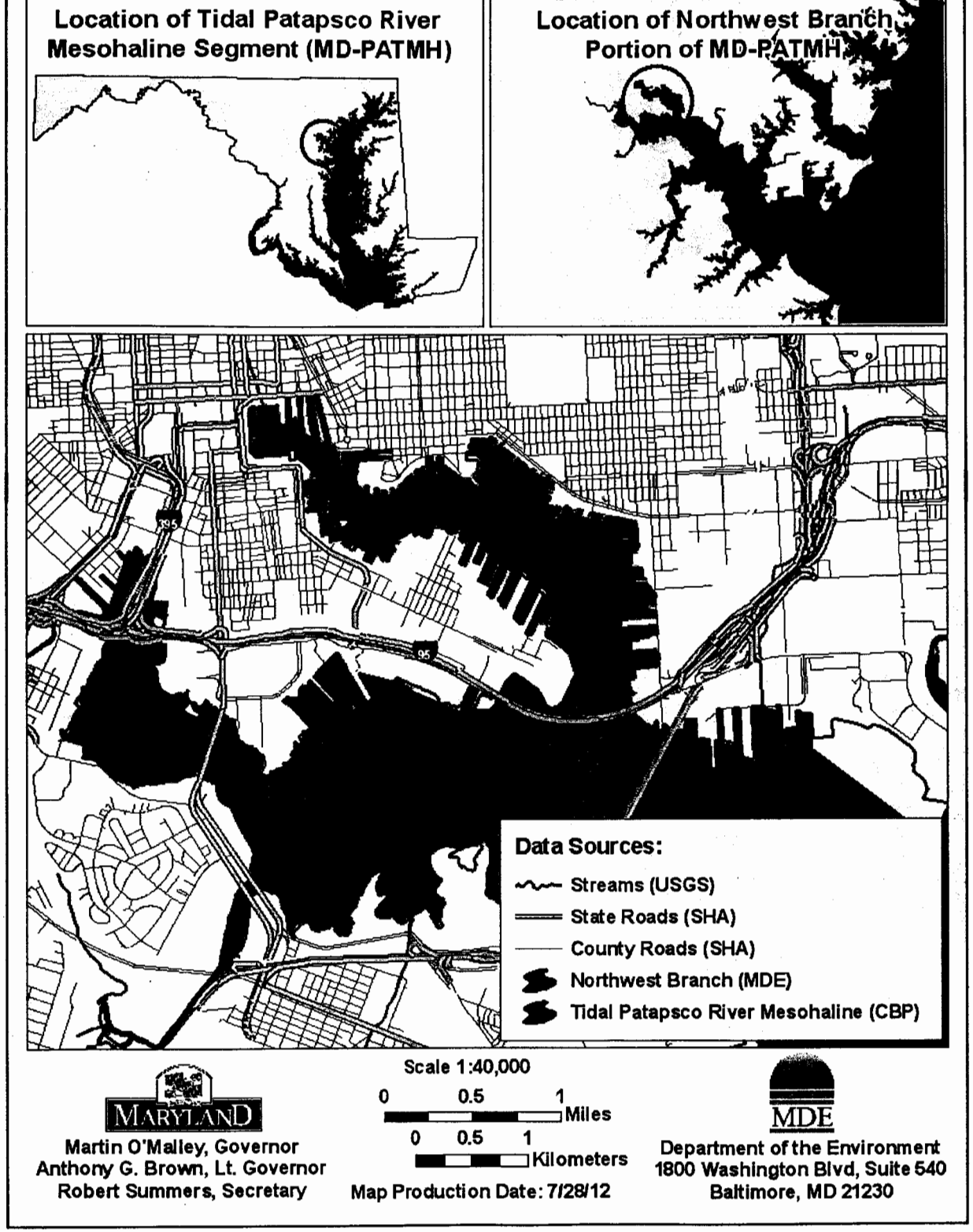


Figure 2.1: Location Map of Northwest Branch Embayment

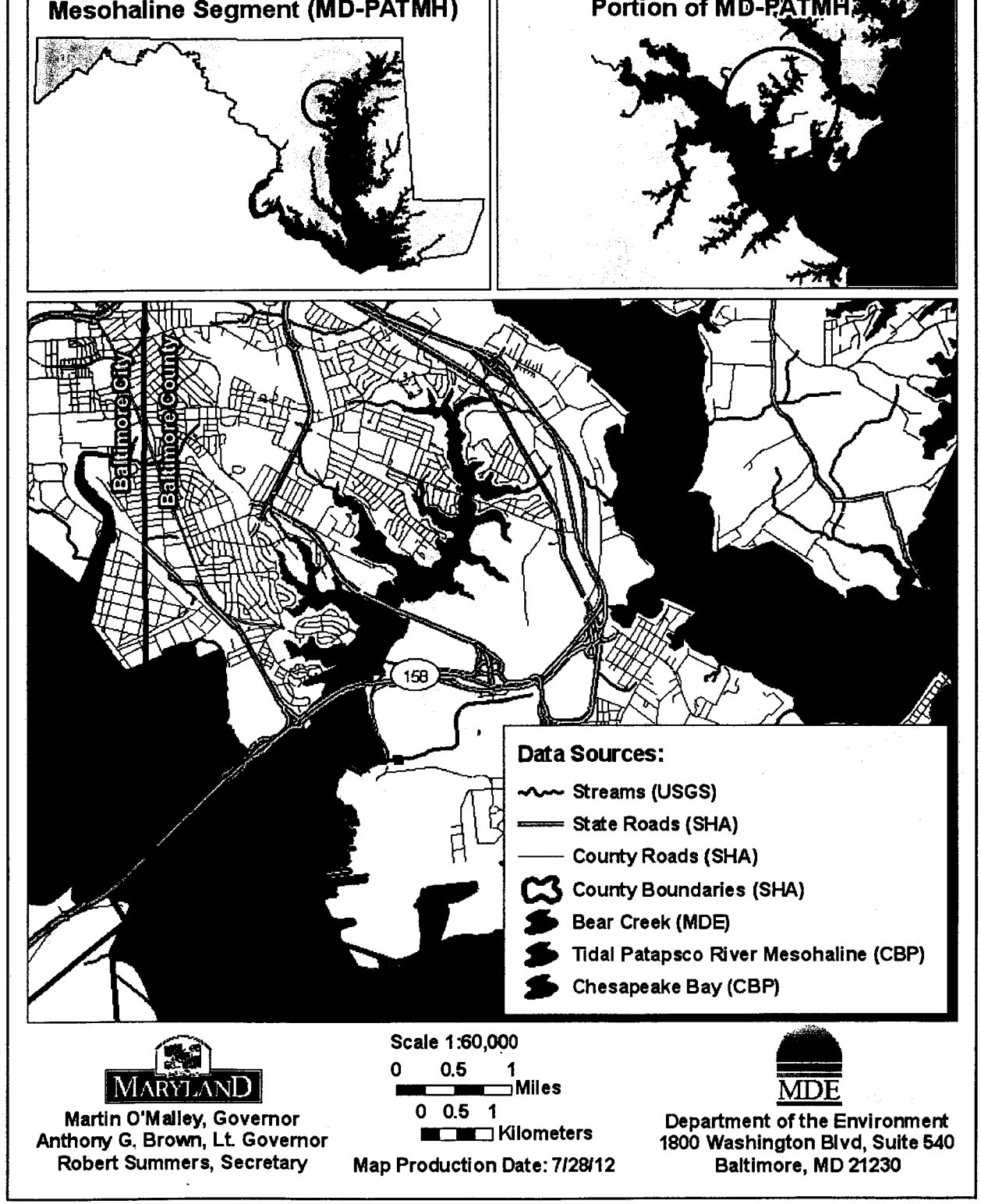


Figure 2.2: Location Map of Bear Creek Embayment

The Northwest Branch and Bear Creek watersheds lie within the Coastal Plain geologic province of Maryland. A portion of the Jones Falls watershed which drains to the Northwest Branch embayment lies within the Piedmont geologic province. The Coastal Plain geologic province is characterized by broad upland areas with low slopes, gentle drainage, and deep sedimentary soil complexes that support broad meandering streams. The sediments of the Coastal Plain dip eastward at a low angle, generally less than one degree and range in age from Triassic to Quaternary. The mineral resources of the Coastal Plain are primarily sand and gravel, which are used as aggregate materials by the construction industry. The Piedmont geologic province is characterized by gentle to steep rolling topography, low hills and ridges. The surficial geology is characterized by crystalline igneous and metamorphic rocks of volcanic origin consisting primarily of schist and gneiss (DNR 2012; MGS 2012).

Soil type for the Northwest Branch and Bear Creek watersheds are categorized by the United States Department of Agriculture (USDA) Soil Conservation Service (SCS) into four hydrologic soil groups: Group A soils have high infiltration rates and are typically deep well drained/excessively drained sands or gravels; Group B soils have moderate infiltration rates and consist of moderately deep-to-deep and moderately well-to-well drained soils, with moderately fine/coarse textures; Group C soils have slow infiltration rates with a layer that impedes downward water movement, and they primarily have moderately fine-to-fine textures; Group D soils have very slow infiltration rates consisting of clay soils with a permanently high water table that are often shallow over nearly impervious material. The Northwest Branch including the Jones Falls watershed is composed primarily of Group B soils at 43.6%, with Group D, Group C, and Group A soils accounting for 32.0%, 20.3%, and 4.1% of the remaining watershed, respectively. The Bear Creek watershed is composed primarily of Group A soils at 48.9%, with Group C, Group B, and Group D accounting for 28.6%, 12.3%, and 10.2% of the remaining watershed, respectively (USDA 2013).

Land Use

According to the United States Geological Survey (USGS) 2006 land-cover data modified for the Chesapeake Bay watershed (USGS 2011), land-use in the Northwest Branch, including the Jones Falls Watershed and Bear Creek watershed can be classified as predominately urban. Urban land occupies approximately 65.79 % (28,319 acres) of the Northwest Branch watershed, while 26.46 % (11,391 acres) is forest, 5.25 % (2,261 acres) is agricultural, 2.50 % (1,075 acres) is covered by water (e.g., open waters of the embayment itself, streams, ponds, etc), and 0.3 % (137 acres). Urban land occupies approximately 72.56 % (5,414 acres) of the Bear Creek watershed, while 26.08 % (1,946 acres) is covered by water, 1.34 % (100 acres) is forest, and 0.02 % (2 acres) is agricultural. The land use for Northwest Branch and Bear Creek watershed, are displayed in Figures 2.3 and 2.4, respectively. The land use distributions (%) for Northwest Branch and Bear Creek watershed are presented in Figure 2.5.

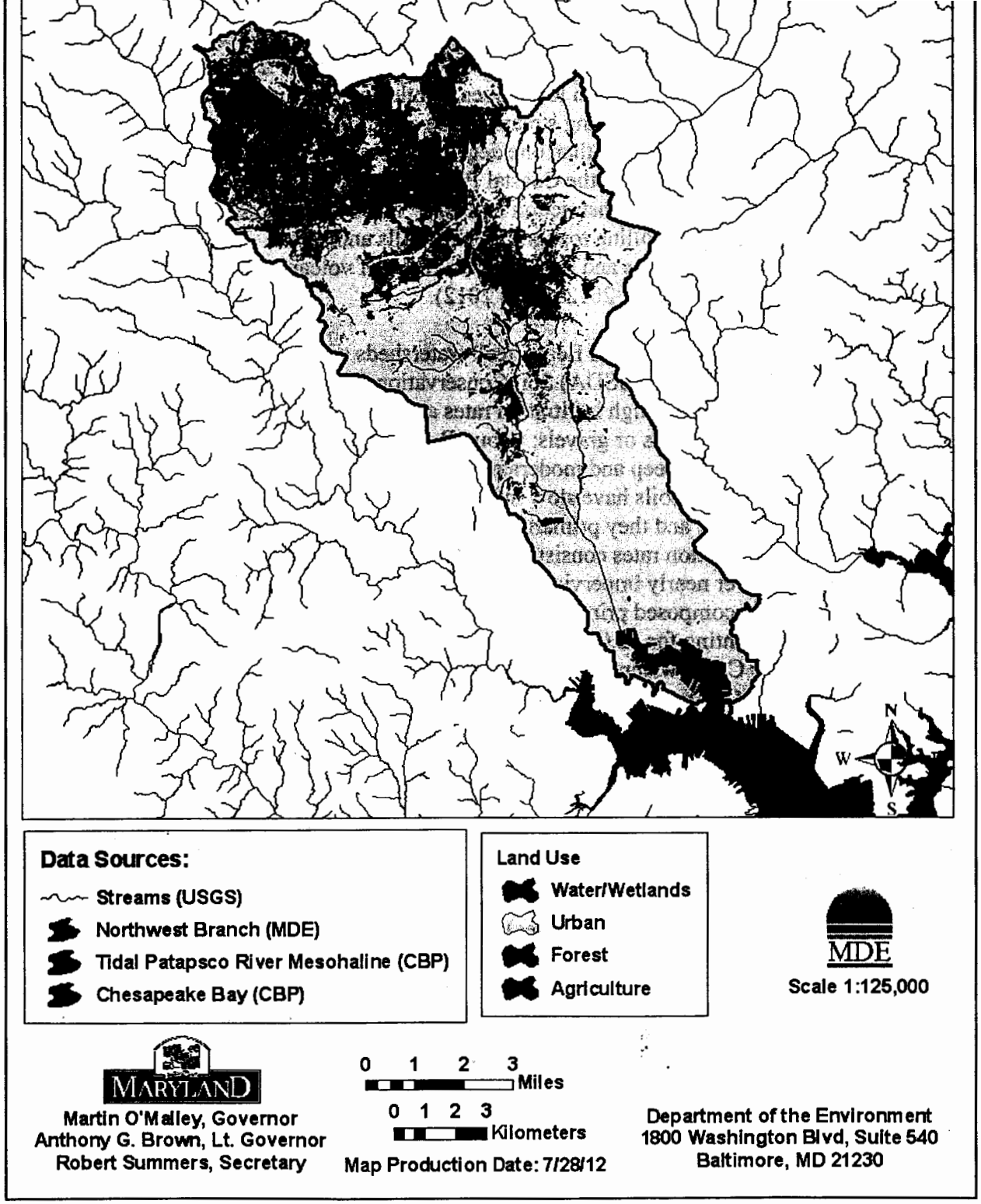


Figure 2.3: Land Use Map of Northwest Branch Watershed

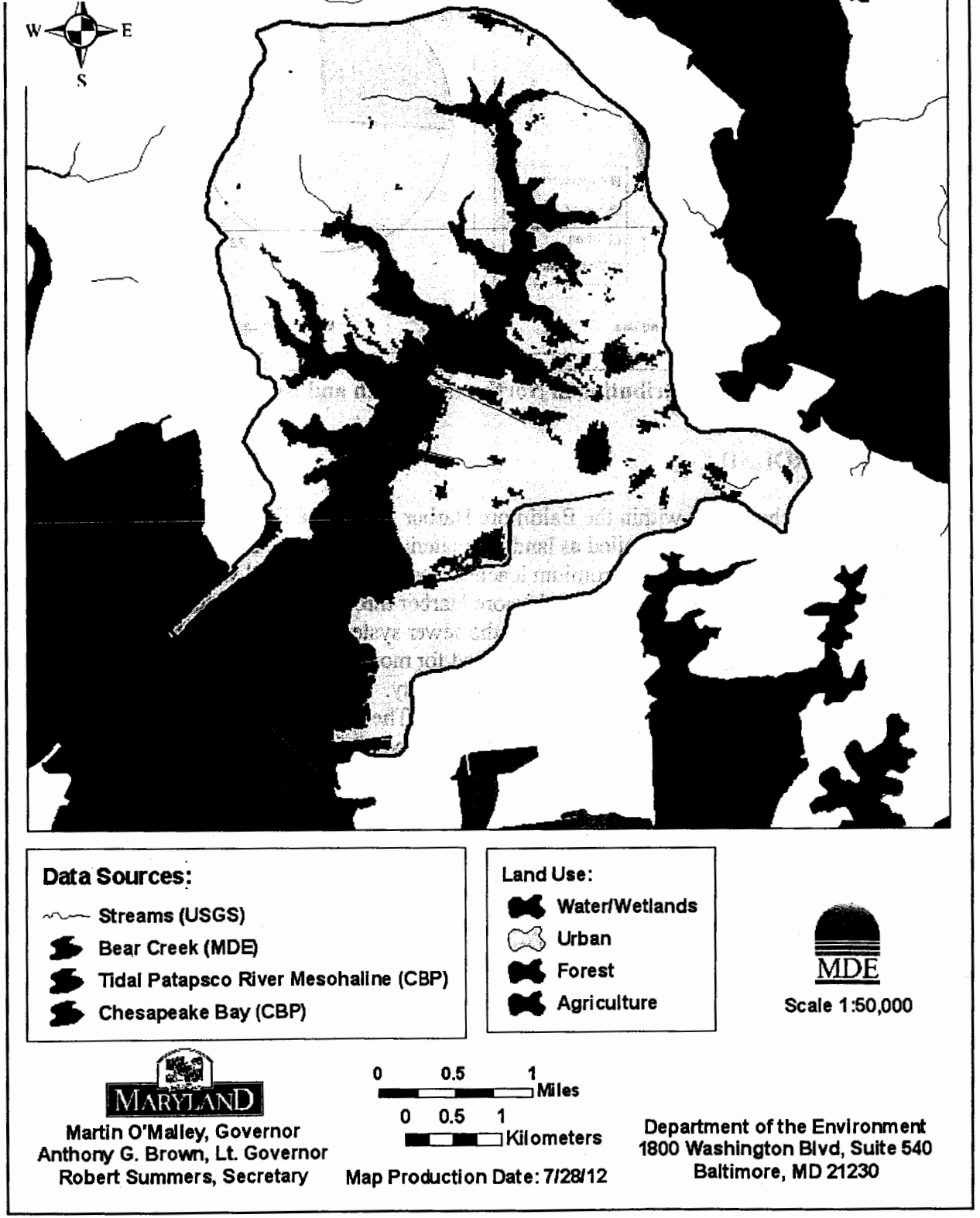


Figure 2.4: Land Use Map of Bear Creek Watershed

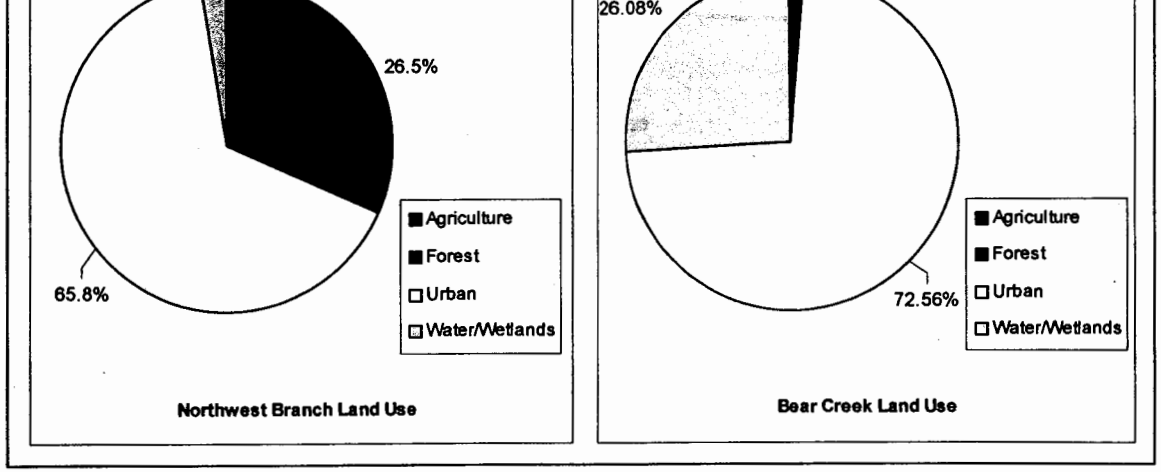


Figure 2.5: Land Use Distribution in Northwest Branch and Bear Creek Watersheds

3.0 BACKGROUND

A major source of chromium within the Baltimore Harbor is Chrome Ore Processing Residue (COPR) which was historically applied as land fill material at DMT and extensively through out the Baltimore Harbor watershed. Chromium leaches from COPR material when in contact with water and subsequently transports to the Baltimore Harbor through groundwater as well as stormwater discharges due to infiltration within the sewer system. COPR was a byproduct of a chrome processing and manufacturing plant operated for more than 140 years by the Mutual Chemical Company and Allied Chemical in Baltimore City. Operations at the plant ceased in 1985 and the COPR is no longer applied as fill material. The former industrial site underwent Brownfields redevelopment and is now designated as Harbor Point, which is currently being developed as a commercial and residential property within the Baltimore Harbor (Honeywell International Inc. 2007).

Chromium present within the aquatic environment (water column or sediment) exists in two oxidation states, trivalent (Cr (III)) or hexavalent (Cr (VI)). The distinction between these two oxidation states is significant due to the toxicity associated with each species; Cr (III) is relatively non-toxic at levels typically found within the environment and Cr (VI) is highly toxic. Reduction/oxidation (Redox) conditions within the water column or sediment govern the speciation of chromium. Within Northwest Branch and Bear Creek, low levels of dissolved oxygen (DO) in the water column and elevated levels of biologically oxygen demanding (BOD) substances, produce anoxic conditions within the sediment supporting a reducing environment. Reductants present within the sediment (total organic carbon (TOC), acid volatile sulfides (AVS), and divalent iron (Fe (II))) facilitate the conversion of Cr (VI) to Cr (III). Cr (III) exhibits low solubility and will undergo reactions to form stable oxides/hydroxides resulting in partitioning from pore water to sediment. As Cr (III) is not present in the pore water at elevated levels under these conditions, it is no longer bioavailable to sediment dwelling organisms through the mechanisms of respiration and dermal absorption. Therefore, chromium remains bound in the sediment in its trivalent state and has no toxicological impact on benthic life.

MDE completed a WQA in 2004 in order to remove the impairment listings of chromium in sediments for Northwest Branch and Bear Creek from Maryland's Integrated Report. EPA delayed approval of this delisting contingent upon the findings of a Toxicity Identification and Evaluation (TIE) study in Baltimore Harbor sediments underway at the time. The TIE study was unsuccessful due to experimental error and thus failed to demonstrate that metals including chromium are not a source of toxicity in the sediments of Baltimore Harbor. Therefore, the delisting decision could not be approved by EPA and the chromium impairment listings remained in Category 5 of Maryland's Integrated Report. The following sections present a summary of the 2004 WQA and TIE study.

4.1 Water Quality Analysis of Chromium in the Northwest Branch and Bear Creek Portions of Baltimore Harbor

A WQA of chromium in the Northwest Branch and Bear Creek portions of Baltimore Harbor was originally submitted to EPA in August 20, 2004. The WQA presented an assessment of newly collected water quality data which indicated that toxicity was present in the sediments of Northwest Branch and Bear Creek, but the source of toxicity could not be attributed to the presence of chromium and TMDL development would therefore be unnecessary. The WQA stated that the chromium listings in Maryland's Integrated Report should be removed from Category 5 ("waterbody is impaired, does not attain the water quality standard, and a TMDL is required") and placed in Category 2 ("waterbody in meeting some [in this case chromium related] water quality standards, but with insufficient data to assess all impairments"). The WQA also stated that the Northwest Branch and Bear Creek embayments should remain listed for biological impacts due to the presence of sediment toxicity from existing data presented in the WQA (MDE, 2004).

The original listings for chromium in sediments from Maryland's 1998 Integrated Report were established using the Sediment Quality Triad (SQT) approach, the designated methodology for assessing waters of the State for toxic impairments in sediment as Maryland has no numeric sediment quality criterion for chromium (MDE 2012a). Water quality data demonstrated that sediment toxicity and a degraded benthic community were present within the Inner Harbor/Northwest Branch and Bear Creek and sediment concentrations for total chromium exceeded the Sediment Quality Guideline (SQG) Effects Range Median (ERM). These findings indicated that the sediment was impaired for chromium. In retrospect this approach was methodologically flawed as a comparison of sediment concentrations and the ERM for total chromium of 370 mg/kg did not take into consideration the relative toxicity associated with the speciation of Cr (III) and Cr (VI). The sediments within the Northwest Branch and Bear Creek support a reducing environment indicating that Cr (III), the relatively non-toxic species at levels typically found within the environment, is the predominant form of chromium present within the sediment (MDE, 2004).

locations is presented in Figure 4.1.1. Water column samples were analyzed for dissolved phase concentrations of Cr (III) and Cr (VI). Sediment samples were analyzed for Cr (III) and Cr (VI) in pore water and total Cr in sediments. AVS-Simultaneously Extracted Metals (SEM) analyses were also conducted on sediment samples (MDE, 2004).

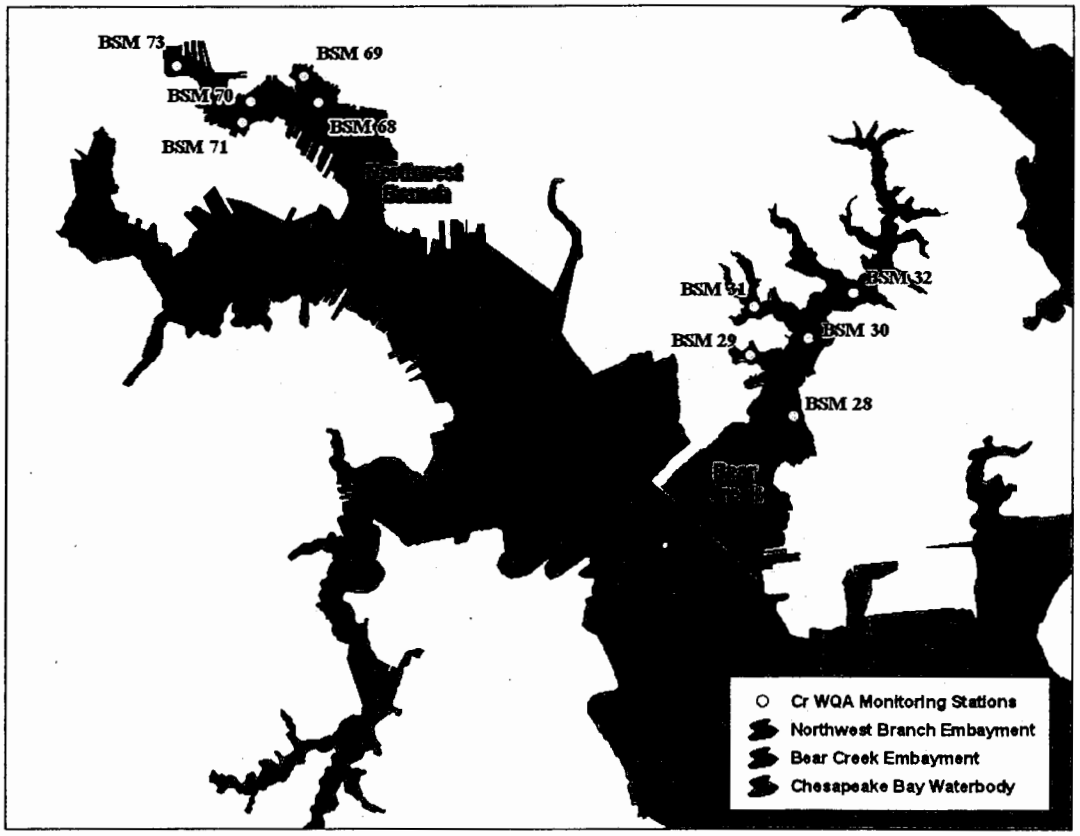


Figure 4.1.1: Chromium WQA Monitoring Stations

In order to evaluate the water quality data for this WQA, a comparison was made between the dissolved water column and sediment pore water concentrations for Cr (III) and Cr (VI) and the aquatic life water column chronic criterion for Cr (VI) (11 µg/L for freshwater and 50 µg/L for saltwater). The mean concentration of dissolved water column data for Cr (III) and Cr (VI) in the Northwest Branch was 0.131 µg/L and 0.203 µg/L, respectively. The mean concentration of dissolved water column data for Cr (III) and Cr (VI) in Bear Creek was 0.212 µg/L and 0.162 µg/L, respectively. The mean concentration of pore water data for Cr (III) and Cr (VI) in the Northwest Branch was 0.35 µg/L and non-detect (ND), respectively. The method detection level for the Cr (VI) analysis was 0.022 µg/L. The mean concentration of pore water data for Cr (III) and Cr (VI) in Bear Creek was 0.11 µg/L and ND, respectively. Water column and pore water Cr concentration data is presented in Table 4.1.1 (MDE, 2004).

Concentration Data

Embayment	Station	Water Column Concentration (µg/L)		Pore Water Concentration (µg/L)		Cr (VI) Aquatic Life Chronic Criterion (µg/L)	
		Cr (III)	Cr (VI)	Cr (III)	Cr (VI)	Freshwater	Saltwater
Northwest Branch	BSM68	0.222	0.279	0.07	ND	11	50
	BSM69	0.129	0.163	0.31	ND	11	50
	BSM70	0.125	0.262	0.50	ND	11	50
	BSM71	0.109	0.131	0.50	ND	11	50
	BSM73	0.070	0.178	0.36	ND	11	50
Bear Creek	BSM28	0.263	0.176	0.05	ND	11	50
	BSM29	0.171	0.175	0.12	ND	11	50
	BSM30	0.355	0.143	0.09	ND	11	50
	BSM31	0.138	0.168	0.12	ND	11	50
	BSM32	0.132	0.148	0.17	ND	11	50

All dissolved water column and pore water concentration data were well below the most conservative threshold of 11 µg/L for the freshwater aquatic life chronic (Cr (VI)) criterion. No Cr (VI) was detected in any pore water sample. The freshwater criterion was applied in this analysis as the salinity for these waters ranged between 1 and 10 parts per thousand (ppt) and MDE (2012) designates that the most conservative of the freshwater and saltwater criterion should be applied under these conditions (MDE, 2004).

The mean sediment concentration of total chromium in Northwest Branch was 752 mg/kg. The mean SEM concentration for Chromium, mean SEM concentration for remaining divalent metals and mean AVS concentration and mean excess sulfide concentration in the Northwest Branch was 3.40 micromoles (µmole)/g, 8.17 µmole/g, 210.94 µmole/g, and 199.37 µmole/g, respectively. The mean sediment concentration of total chromium in Bear Creek was 741 mg/kg. The mean SEM concentration for Cr, mean SEM concentration for remaining divalent metals, mean AVS concentration and mean excess sulfide concentration in the Bear Creek was 6.93 µmole/g, 22.23 µmole/g, 332.75 µmole/g, and 303.58 µmole/g, respectively. Sediment concentration data for Northwest Branch and Bear Creek is presented in Table 4.1.2 (MDE, 2004).

Table 4.1.2: Northwest Branch and Bear Creek Sediment Concentration Data

Embayment	Station	Total Cr (mg/kg)	SEM Cr (µmole/g)	SEM Metals (µmole/g)	AVS (µmole/g)	Excess Sulfide (µmole/g)
Northwest Branch	BSM 68	443	1.60	7.46	78.75	69.69
	BSM 69	480	2.11	7.91	369.38	359.36
	BSM 70	1,068	4.66	7.59	173.44	161.19
	BSM 71	1,286	6.60	10.78	196.88	179.50
	BSM 73	500	2.01	7.13	236.25	227.11
Bear Creek	BSM 28	705	6.92	19.42	144.06	117.72
	BSM 29	724	6.20	21.29	304.06	276.58
	BSM 30	827	10.80	31.58	340.63	298.25
	BSM 31	847	4.73	19.14	500.00	476.13
	BSM 32	601	6.00	19.78	375.00	349.22

The SEM concentration for chromium and total metals were well below the AVS portion present within the sediments of Bear Creek and Northwest Branch providing excess capacity for reducing all chromium within the sediment from Cr (VI) to Cr (III) as well as the formation of sulfide complexes with all remaining divalent metals significantly reducing the bioavailability of these metals to sediment dwelling organisms. The presence of excess AVS indicates that Cr will partition primarily to the sediment as oxide/hydroxide compounds as indicated by the low pore water concentrations of Cr (III) and Cr (VI). While sediment concentrations for Total Cr exceeded the ERM of 370 mg/kg, this is not an indication of toxicity, as the sediments are composed primarily of Cr (III), the relatively non-toxic species of chromium at levels typically found within the environment (MDE, 2004).

The water quality data presented in support of this WQA demonstrated that while sediment toxicity was present, the source of toxicity could not be attributed to the presence of chromium and TMDL development would therefore be unnecessary (MDE, 2004).

The EPA upon review of this WQA provided MDE with a decision rationale letter regarding their approval of this document on January 18, 2005. EPA believed that MDE used the best available science and appropriate methodology in determining that chromium is not a source of

of MDE's conclusions contained within the WQA. However, at the time, MDE was conducting a TIE study to assist in identifying the pollutant(s) responsible for the biological impairment in the Baltimore Harbor which would determine whether there was a need to develop chromium TMDL(s) for the listed segments. For this reason, EPA chose to defer the delisting decision for chromium until the study was complete. Upon confirmation from the TIE study that metals were not a cause of toxicity, the delisting would be approved (US EPA 2005). Description and outcomes of the TIE study are presented below in Section 4.2.

4.2 Toxicity, Identification, and Evaluation and Long-Term Contaminant Trends in the Baltimore Harbor

University of Maryland Center for Environmental Science (UMCES) Chesapeake Biological Laboratory (CBL) and University of Maryland (UM) Wye Research and Education Center (WREC) submitted the "Toxicity, Identification, and Evaluation (TIE) and Long-Term Contaminant Trends in the Baltimore Harbor" report to MDE on February 2007. The objective of this study was to use innovative whole sediment TIE methods to determine the class of chemical contaminants most likely responsible for observed sediment toxicity in the Baltimore Harbor. The sediments of the Baltimore Harbor contain elevated levels of many different chemical contaminants which are highly toxic to the benthic community making it difficult to directly link toxicity to a specific chemical compound or class of chemical contaminants (Klosterhaus *et al.* 2007).

A field survey was conducted to evaluate the chemical composition and toxicity of sediments from locations throughout the Baltimore Harbor. Sediment samples were analyzed for organic contaminants (PCBs, polyaromatic hydrocarbons (PAHs), polybrominated diphenyl ethers (PBDEs), etc…) oragnotins (i.e., tributyltin), and metals in pore water and sediment. Sediment bioassays were conducted with the amphipod *Leptocheirus plumulosus*, an estuarine benthic organism commonly applied by MDE in evaluating sediment toxicity. Eight stations were selected for this study based on toxicity and prevalence of chemical contamination for a multitude of toxic substances observed in previous studies. Four of the stations, BSM 28, BSM 33, BSM 68, and BSM 71 are located in Bear Creek and Northwest Branch. A map displaying the TIE Study station locations is presented in Figure 4.2.1 (Klosterhaus *et al.* 2007).

The whole sediment TIE methods applied in this study were developed by the Atlantic Ecology Division of the EPA in Narragansett, RI which applied the marine amphipod *Ampelisca abdita*, a species generally found in coastal waters with high salinity. *A. abdita* is not a resident species in the Northern Chesapeake Bay due to salinities which fall outside its range of adaptability. Test water for sediment bioassays would require an adjustment to salinity to ensure *A. abdita* survival introducing a potential confounding factor. Therefore the amphipod *L. plumulosus* was applied in this study, as it is a resident species and all previous sediment toxicity work for Baltimore Harbor was conducted using this organism (Klosterhaus *et al.* 2007).

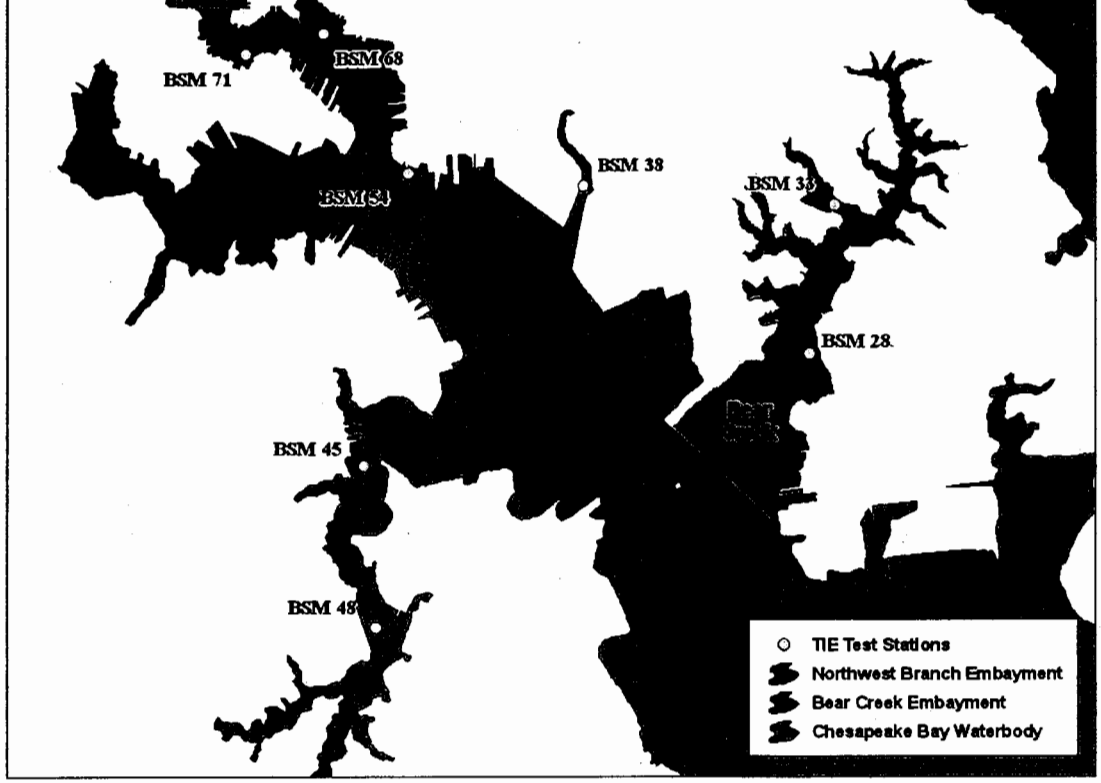


Figure 4.2.1: Baltimore Harbor TIE Study Stations

As the TIE methods were previously developed for *A. abdita* it was necessary to establish that test conditions alone would not result in toxicity to the *L. plumulosus*. Trial laboratory testing was necessary to determine that the sediment manipulations were not directly toxic to the organism by conducting the toxicity test with the individual resin or charcoal and clean sediments to ensure there were no confounding toxicants. In addition, testing was done to ensure beaker size, sediment volume, and test duration did not affect toxicity results (Klosterhaus *et al.* 2007).

Trial testing was successful and the whole sediment TIE method was conducted using the *L. plumulosus*. Sediment manipulations during trial testing were successful in removing each individual class of compounds (ammonia, organics, and metals) with the relevant resin/charcoal to eliminate toxicity in spiked control sediments. However, upon completion, the study was unsuccessful in identifying a class of compounds responsible for toxicity within the sediments of the Baltimore Harbor because when this approach was applied to field sediments, the treatments did not successfully remove toxicity. The TIE methods were successful in removing organics and ammonia, though the resin chosen to sequester metals failed to entirely remove all metals present in the sediment. It is believed that the elevated levels of sulfides in these sediments interfered with the ability of the resin to remove metals from the pore water. In fact, the concentrations of several metals increased in the pore water following manipulation with the resin. Therefore, it was not possible to definitively determine whether metals are a source of toxicity within the sediments of Baltimore Harbor (Klosterhaus *et al.* 2007).

manipulated sediments. These tests found no observed toxicity at several stations, including stations BSM 28, BSM 33, and BSM 68 indicating that metals are not present in pore water at levels that pose a risk to the health of benthic organisms and thus, an unlikely source of toxicity in these sediments. This assessment falls in line with EPA's equilibrium partitioning theory based on the concept that the primary pathway of toxicity in sediments for benthic organisms is from exposure to compounds in pore water through respiration and dermal absorption. Pore water and sediment samples were also collected and analyzed for total Cr and AVS-SEM under the TIE study. The concentrations of total chromium in pore water ranged from 1.48 to 9.04 µg/L for stations located in Northwest Branch and Bear Creek. These levels were all below Maryland's saltwater and freshwater aquatic life chronic Cr (VI) criterion of 50 µg/L and 11 µg/L, respectively. The AVS-SEM analysis demonstrated that AVS concentrations were greater than SEM concentrations for total metals, providing sufficient capacity for reducing chromium to its trivalent state and binding all remaining metals as sulfide complexes in the sediment. Pore water and AVS-SEM concentration data are presented in Table 4.2.1 (Klosterhaus *et al.* 2007).

Table 4.2.1: Baltimore Harbor TIE Study Sediment Concentration Data (Pore Water and AVS/SEM)

Station	Pore Water Total Cr (µg/L)	SEM Cr (µmole/g)	SEM Metals (µmole/g)	AVS (µmole/g)	Excess Sulfide (µmole/g)
BSM 28	1.48	7.84	21.50	16,700	16,678.50
BSM 33	4.33	7.21	5.45	24,700	24,694.55
BSM 38	11.60	0.93	5.45	18,000	17,994.55
BSM 45	1.88	1.76	8.64	2,460	2,451.36
BSM 48	1.98	0.87	6.08	8,920	8,913.92
BSM 54	3.24	1.08	4.96	4,620	4,615.04
BSM 68	4.54	1.93	8.24	4,710	4,701.76
BSM 71	9.04	6.08	14.60	13,100	13,085.40

The results of the TIE study were inconclusive regarding the toxicity of metals in Baltimore Harbor sediments, therefore EPA delayed the delisting decision supported by the Chromium WQA submitted in 2004. Chromium remained listed as an impairing substance in Northwest Branch and Bear Creek on Maryland's Integrated Report. The John's Hopkins University (JHU) Center for Contaminant Transport, Fate, and Remediation (CTFR), under the direction of Dr. Edward Bouwer, professor and department chair of Geography and Environmental Engineering, conducted several studies investigating the relationship between toxicity and the exposure of chromium to benthic organisms, sediment ingestion as a pathway of toxicity, and stability of Cr (III) under oxygenation in the sediments of Baltimore Harbor to assist MDE in assessing the potential ecological impact of chromium in sediments. In addition to these studies provided by JHU CTFR, an ERA of DMT and an EPA Data Evaluation of Bear Creek sediments were recently completed investigating the potential ecological impact from chromium. The following sections present a summary of these five individual studies which establish that Cr is not a source of toxicity within the sediments of Northwest Branch and Bear Creek.

5.1 John's Hopkins University Studies Investigating Chromium Speciation and Benthic Toxicity in Baltimore Harbor Sediments

5.1.1 Bioassay Testing of Baltimore Harbor Sediments Spiked with Cr (VI)

JHU CTFR completed the study "Bioassay Testing of Baltimore Harbor Sediments Spiked with Cr (VI)" on February 12, 2008. Dr. Bouwer, director of the JHU CTFR, is a co-author of this study. The primary objective of this study was to determine if there is a relationship between toxicity and the exposure of chromium to benthic organisms inhabiting Baltimore Harbor sediments. Whole sediment bioassays were conducted using the amphipod *Leptocheirus Plumulosus* and exposing the test organism to sediments from the Baltimore Harbor spiked with increasing levels of Cr (VI). This amphipod was selected for testing as it is a resident species of the Baltimore Harbor, it is sensitive to chemical contaminants and has a tendency to burrow in and ingest sediment (Watlington *et al.* 2008).

Previous studies presented in this document established that Cr (III) is the predominant species in sediment due to elevated sulfide levels which maintain a reducing environment. Cr (III) exhibits low solubility and will partition from pore water to sediment primarily as insoluble oxide/hydroxide compounds. The previous WQA presented water quality data demonstrating that chromium concentrations in pore water were well below numeric criterion supportive of the protection of aquatic life designated use and pore water toxicity tests conducted under the TIE study found no toxicity due to metals. While this information indicated that chromium is not a source of toxicity in sediments, these studies only consider pore water as the primary route of exposure through respiration and dermal absorption and did not investigate whether sediment ingestion of chromium is a also a contributing pathway for potential toxicity to benthic organisms (Watlington *et al.* 2008).

In this study both acute (10-day) and chronic (28 day) whole sediment bioassays were conducted on the test organism. Test sediments were spiked at three different levels of Cr (VI) from five stations throughout the Baltimore Harbor. Two of these stations, BSM 68 and BSM 33, were located in Northwest Branch and Bear Creek, respectively. Sample sites were selected based on information from previous surveys conducted in the Baltimore Harbor (e.g., TIE Study) in which geochemical properties (TOC, grain size, etc…), chemical contaminant concentrations and toxicity were measured. A map displaying the monitoring stations locations are presented in Figure 5.1.1(a). Sediments from selected sites could not exhibit more than 50% mortality to test organisms in a baseline acute whole sediment bioassay so that potential changes in toxicity with increasing Cr (VI) spike concentrations would be observable (Watlington *et al.* 2008).

Baseline Cr concentrations of the selected test sites were previously found to range between 200 and 850 mg/kg. The first spiking level (range of 383-677 mg/kg) was chosen to span the observed range of concentrations from the test sites to be representative of environmental conditions. The second and third spiking level, (1250-1810 mg/kg) and (2000-4180 mg/kg), respectively, were chosen to assess the level of Cr (VI) necessary to elicit an acute or chronic toxicological response to test organisms. These levels significantly exceed environmentally relevant levels of measured total Cr concentrations in Baltimore Harbor sediments. Sediment concentration data of total Cr for baseline and spiked treatments are presented in Table 5.1.1(a). (Watlington *et al.* 2008).

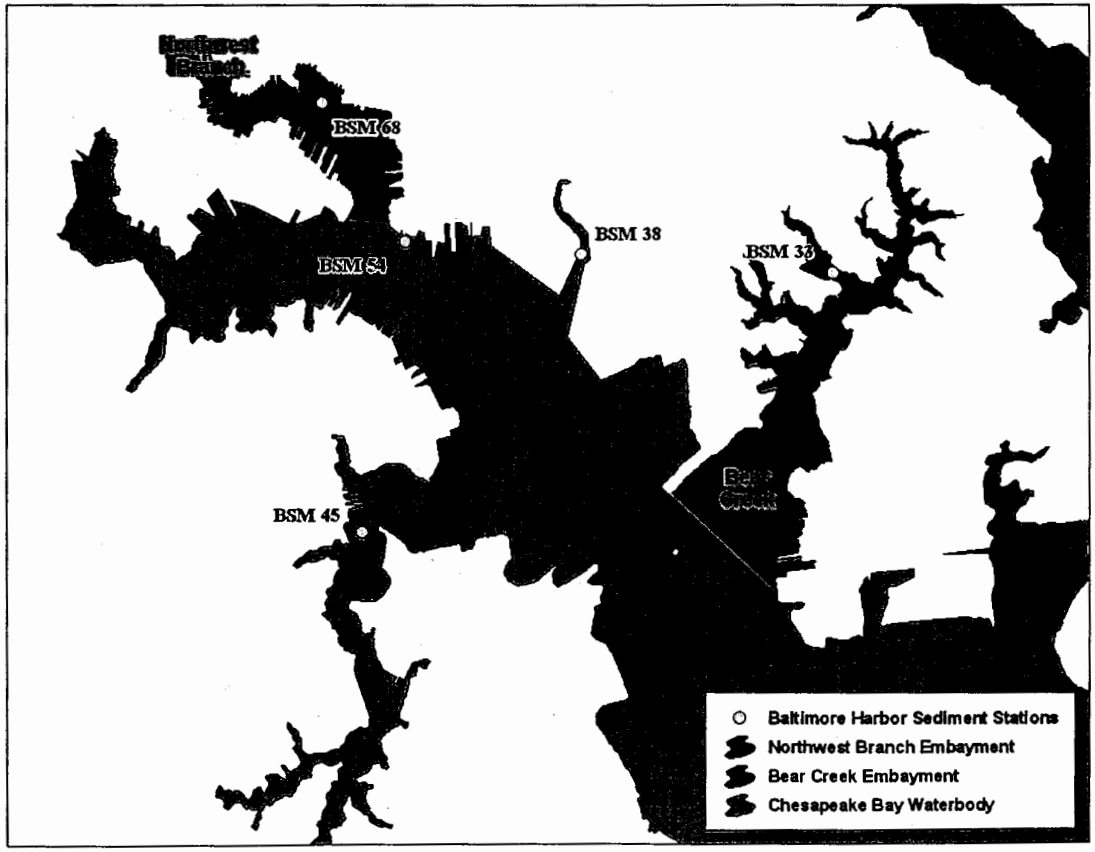


Table 5.1.1(a): Total Chromium Sediment Concentration Data (Baseline & Spiked Levels)

Station	Total Cr (Baseline) (mg/kg)	Spike A (mg/kg)	Total Cr (post Spike A) (mg/kg)	Spike B (mg/kg)	Total Cr (post Spike B) (mg/kg)	Spike Cr (mg/kg)	Total Cr (post Spike C) (mg/kg)
BSM 33	823	677	1500	1650	2470	2000	2820
BSM 38	271	383	654	1310	1580	3090	3360
BSM 45	148	400	548	1670	1820	4180	4330
BSM 54	126	408	535	1250	1380	2920	3050
BSM 68	354	610	964	1810	2160	3210	3560

The results of both the acute and chronic whole sediment bioassays established that no spiked sediment treatment displayed elevated toxicity when compared with the baseline treatments, except for one station (BSM 68) where the highest spiking level of 3210 mg/kg resulted in significant mortality. Results of the chronic whole sediment toxicity tests for baseline and spiked treatments are presented in Table 5.1.1(b) and Figure 5.1.1(b) (Watlington *et al.* 2008).

Table 5.1.1(b): Whole Sediment Chronic Toxicity Test Results (Baseline & Spiked Levels)

Treatment	Matrix	Stations				
		BSM 33	BSM 38	BSM 45	BSM 54	BSM 68
Baseline	Total Cr (mg/kg)	823	271	148	126	354
	Survival (%)	32	37	86	76	56
Spike A	Total Cr (mg/kg)	1325	654	548	535	964
	Survival (%)	33	50	72	78	67
Spike B	Total Cr (mg/kg)	2466	1580	1820	1380	2160
	Survival (%)	47	53	88	73	57
Spike C	Total Cr (mg/kg)	2820	3360	4330	3050	3560
	Survival (%)	34	60	93	82	0

All baseline and spiked sediment samples used for toxicity assessment were also analyzed for Cr (VI) concentrations. This information is presented in Table 5.1.1(c) Concentrations of Cr (VI) in spiked sediments were within the same range as the baseline sediments with the exception of the high level spiking for BSM 68 of 9.57 mg/kg which contained Cr (VI) in sediment approximately 150 times the baseline concentration. Cr (VI) concentrations in sediment for baseline treatments were between 0.05 and 0.08 mg/kg while concentrations for spiking treatments excluding the high level spiking for BSM 68 ranged between zero and 1.37 mg/kg.

of the total mass of chromium (Watlington *et al.* 2008).

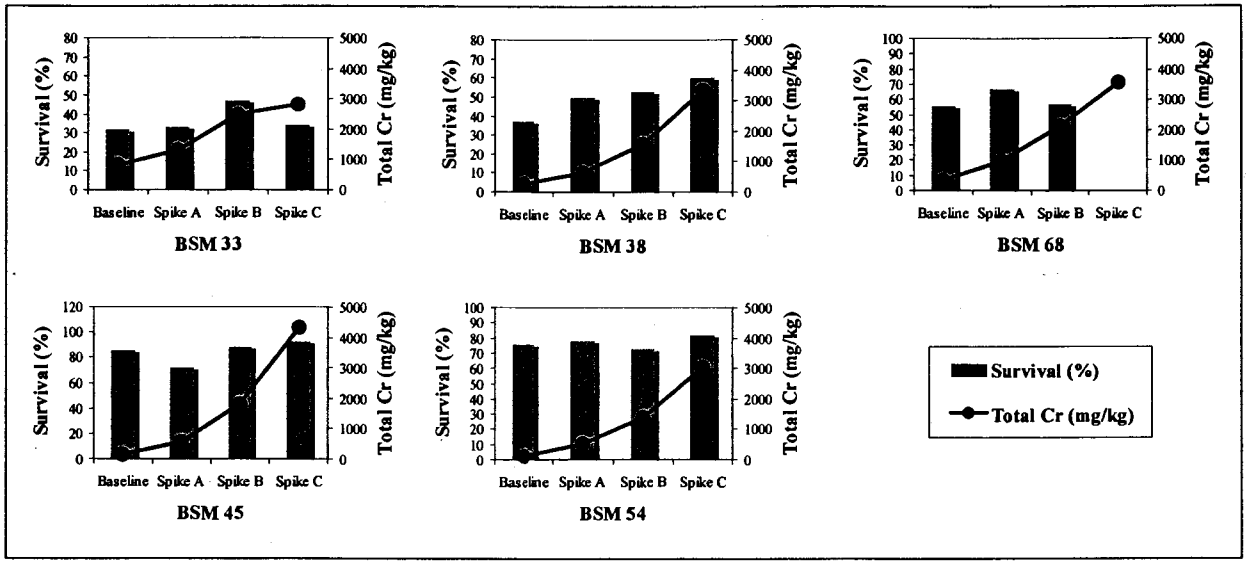


Figure 5.1.1(b): Whole Sediment Chronic Toxicity Test Results (Baseline & Spiked Levels)

The overlying water from the test beakers for each sediment treatment was also analyzed for total chromium and Cr (VI). This information is also presented in Table 5.1.1(c). No Cr (VI) was detected in any treatment except for the high level spiking for BSM 68 at a concentration of 1054.1 µg/L which was well above the saltwater aquatic life Cr (VI) criterion of 50 µg/L. An additional spiking evaluation was conducted for station BSM-68 to determine the true lowest observed apparent effects level (LOAEL) for which toxicity would be observed between the no affects level of 1810 mg/kg and effects level of 3210 mg/kg from the previous analysis. The LOAEL threshold spiking concentration was determined to be approximately 2,250 mg/kg. This concentration was well above the range of environmentally relevant concentrations within Baltimore Harbor sediments as baseline concentrations did not exceed 823 mg/kg (Watlington *et al.* 2008).

Cr (VI) concentrations in sediment were not detected in all spiking treatments except for the high level spiking at BSM 68, therefore the existing reducing capacity within the sediments is sufficient to facilitate the complete conversion of Cr (VI) additions to Cr (III). To further demonstrate this, an AVS-SEM analysis was conducted on sediments for all spiking treatments. The molar ratio of Cr (VI) additions to AVS for each spiking treatment is presented in Table 5.1.1(d).

Levels)

Treatment	Matrix	Analyte	Station				
			BSM 33	BSM 38	BSM 45	BSM 54	BSM 68
Baseline	Sediment (mg/kg)	Total Cr	823	271	148	126	354
		Cr (VI)	0.05	0.05	0.05	0.08	0.06
	Overlying Water (µg/L)	Total Cr	0.05	13.4	0.1	0.5	0.8
		Cr (VI)	ND	ND	ND	ND	ND
Spike A	Sediment (mg/kg)	Total Cr	1325	654	548	535	964
		Cr (VI)	0.00	0.01	0.01	1.37	0.36
	Overlying Water (µg/L)	Total Cr	ND	ND	0.3	ND	1.7
		Cr (VI)	ND	ND	ND	ND	ND
Spike B	Sediment (mg/kg)	Total Cr	2466	1580	1820	1380	2160
		Cr (VI)	0.00	0.01	0.00	0.27	1.10
	Overlying Water (µg/L)	Total Cr	ND	1.6	1.5	2.7	3.1
		Cr (VI)	ND	ND	ND	ND	ND
Spike C	Sediment (mg/kg)	Total Cr	2820	3360	4330	3050	3560
		Cr (VI)	0.02	0.03	0.02	0.80	9.57
	Overlying Water (µg/L)	Total Cr	ND	1.6	1.3	9.2	1455.9
		Cr (VI)	ND	ND	ND	ND	1054.1

Table 5.1.1(d): Cr (VI)/AVS Molar Ratios (Spiked Levels)

Treatment	Molar Ratio	Station				
		BSM 33	BSM 38	BSM 45	BSM 54	BSM 68
Spike A	Cr (VI) addition /AVS	0.03	0.08	0.08	0.17	0.32
Spike B		0.06	0.28	0.33	0.51	0.96
Spike C		0.11	0.67	0.83	1.19	1.71

A ratio below one indicates that AVS is present at levels providing sufficient capacity to reduce all Cr (VI) to Cr (III). All ratios were below one except for the high level spiking at BSM 54 and BSM 68. This analysis found that the LOAEL for the high level spiking at BSM 68 occurred when the molar ratio exceeded one. In this treatment, Cr (VI) was no longer completely reduced to Cr (III) and therefore remained in the dissolved phase of the overlying water and pore water during the bioassay resulting in the death of all test organisms (Watlington *et al.* 2008). While the molar ratio for BSM 54 exceeded one, no toxicity was observed in the spiking treatment. This indicated that reductants other than AVS were present in the sediment, such as Fe (II) or TOC, which provided sufficient reducing capacity to convert all Cr (VI) in the spiking addition when AVS was no longer available (Watlington *et al.* 2008).

The bioassay testing of Baltimore Harbor sediments concluded that, with the exception of the high level spiking treatment for BSM 68, toxicity values did not vary from those observed for the baseline treatments. No correlation was observed between sediment toxicity and total chromium concentrations. The baseline treatments for some stations exhibited pre-existing chronic toxicity while levels of mortality in subsequent spiked treatments were not elevated with respect to the baseline treatments, excluding the high level spiking treatment for BSM-68. The addition of Cr (VI) to sediments at concentrations at or exceeding environmentally relevant concentrations caused no increases in observed toxicity, with the exception of the high level spiking treatment for BSM 68. This finding indicated that pre-existing chromium in the baseline sediment treatments did not contribute to any observed toxicity. If chromium already present in the baseline sediment was responsible for toxicity, an increase in mortality would have occurred with minimal addition of chromium. These findings indicated that chromium is not responsible for observed toxicity in Baltimore Harbor sediments evaluated in this study. As a result of the toxicity observed in Station BSM-68 and the AVS-SEM analysis, it can be concluded that AVS constituents are the major contributor to Cr (VI) reduction in anoxic sediments. A geochemical condition in sediment where Cr (VI) exceeds AVS is an indicator of potential toxicity (Watlington *et al.* 2008).

5.1.2 The Sediment Ingestion Pathway as a Source of Toxicity in the Baltimore Harbor

JHU CTFR submitted the literature review "The Sediment Ingestion Pathway as a Source of Toxicity in the Baltimore Harbor" to MDE on January 4, 2007. Dr. Bouwer, director of the JHU CTFR, is a co-author of this study. This document provides additional information on previous studies that investigated sediment ingestion of Cr (III) as a pathway for toxicity to benthic organisms (Watlington *et al.* 2007).

Berry *et al.* (2002) conducted several studies using marine sediments and the amphipod *Ampelisca abdita* to demonstrate that sediment containing levels of Cr (III) well above the ERM of 370 mg/kg for total chromium is not acutely toxic to the test organism. A whole sediment acute bioassay was conducted on sediments with Cr (III) concentrations ranging from less than 50 mg/kg to levels greater than 3,000 mg/kg. There was no observed relationship demonstrating changes in toxicity with increasing Cr (III) concentrations. No acute toxicity was observed even

Berry *et al.* (2002) also conducted a water only toxicity test using the amphipod *A. abdita*. A test solution with a maximum Cr (III) concentration of 100,000 µg/L was introduced while adjusting pH to maintain conditions similar to natural seawater. As Cr (III) exhibits low solubility, a precipitate was formed at the base of the test chamber. Amphipods were placed in the chamber and resided on the pure Cr (III) precipitate for a test duration of 10 days. The amphipods lived in the precipitate for the entire 10-day period and utilized the precipitate in building tubes for burrowing as is typically done by the organism within sediment. No toxicity was observed while the amphipods lived within the pure Cr (III) precipitate for the duration of the test (Watlington *et al.* 2007).

Oshida *et al.* (1981) conducted a multigenerational toxicity test with Cr (III) on the marine polychaete, *Neanthes arenaceodentata*. The report states that the polychaete has been shown to be one of the more sensitive benthic macroinvertabrates when tested with chromium. A test solution with a Cr (III) concentration of 50,400 µg/L was prepared, forming a pure Chromium precipitate at the bottom of the test chamber. The study evaluated reproduction of this organism by introducing pairs of male and female *N. arenaceodentata* to the test chambers for a 23 day period to allow birth and development of offspring. The offspring once fully developed were removed and introduced as pairs of male and female *N. arenaceodentata* to test chambers in the same manner as the previous generation. The study found that no biological effects were observed in the polychaetes exposed to Cr (III) and that the Cr (III) precipitate in the long term study did not impact mortality rate, maturation time required for spawning, or the number of offspring per brood. These organisms will not only survive, but reproduce normally, while inhabiting sediment composed of pure Cr (III) precipitate (Watlington *et al.* 2007).

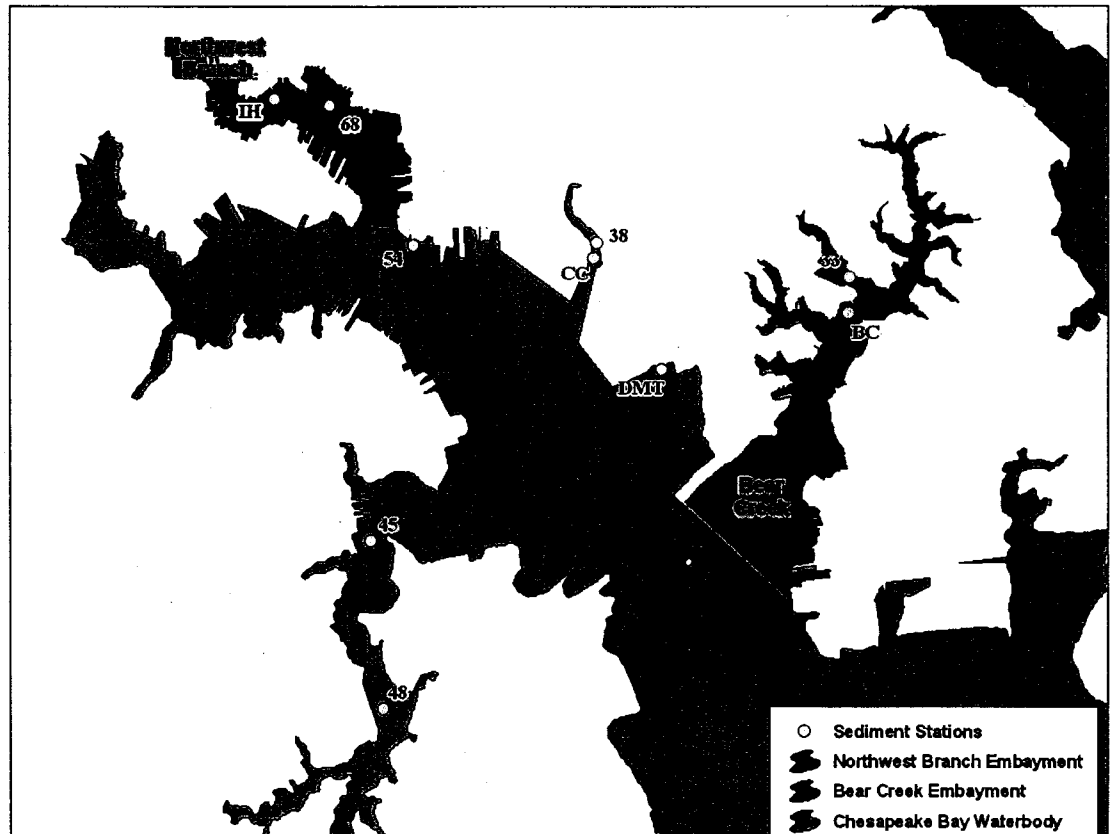
These studies established that Cr (III) is not a source of toxicity to benthic organisms inhabiting the sediment of marine environments. No acute toxicity was observed in marine amphipods when exposed to levels of Cr (III) up to 3000 mg/kg. In addition, marine amphipods and polychaetes did not exhibit a toxicological response when inhabiting pure Cr (III) precipitate for the duration of these tests. These findings are indicative of the inert biological nature of Cr (III) on sediment dwelling organisms. Finally, the data strongly suggests that levels of Cr (III) greater than those found in the Baltimore Harbor sediments are not a source of toxicity to benthic organisms (Watlington *et al.* 2007).

5.1.3 Geochemical Influences on Chromium Speciation and Fate in Estuarine Sediments

The dissertation "Geochemical Influences on Chromium Speciation and Fate in Estuarine Sediments; Importance of Redox Interactions with Manganese Sulfide Minerals" was completed by Amar Wadhawan of the JHU CTFR under the direction of Dr. Bouwer in April 2012. This study investigated chromium speciation and fate in Baltimore Harbor sediments under oxygenation to replicate conditions of sediment resuspension that may occur due to dredging, bioturbation, and flood events. These conditions have the potential to alter biogeochemical conditions (e.g., reducing capacity) in sediments resulting in Cr (III) oxidation and Cr (VI)

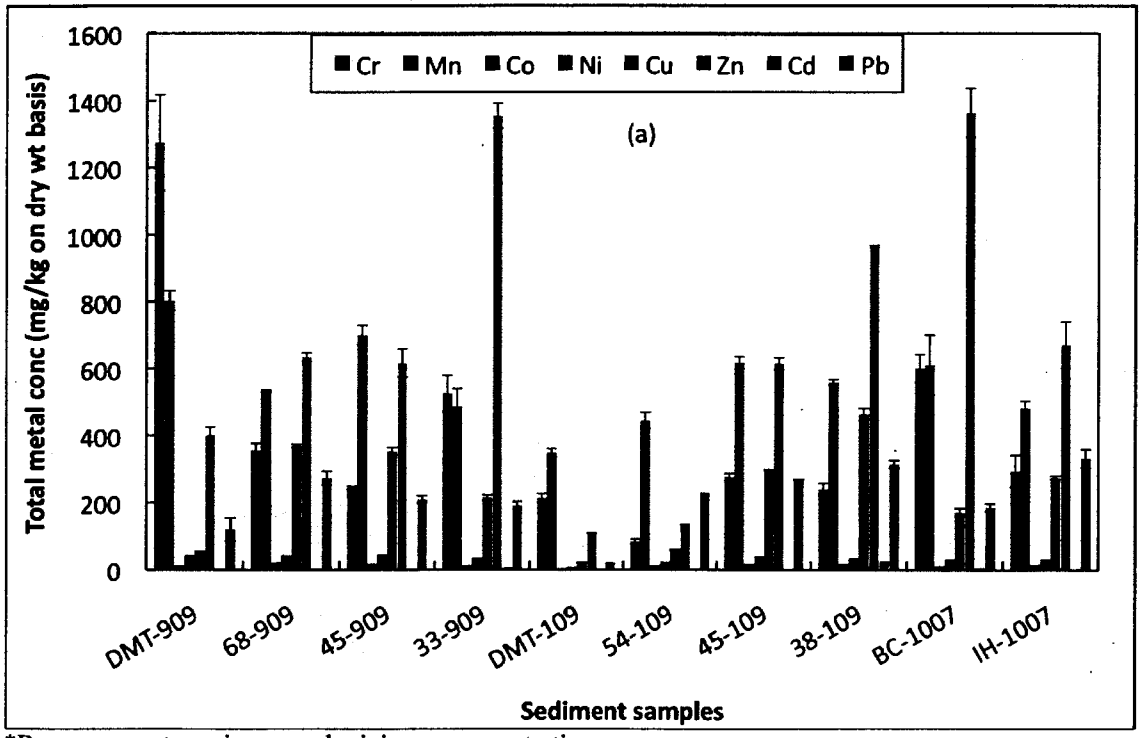
Under existing conditions, sediment samples collected from ten stations throughout the Baltimore Harbor were found to be chemically reducing and devoid of oxygen and Cr (VI), as well as contain a mixture of trace metals of which iron (Fe) and manganese (Mn) were most abundant. A map displaying the sediment stations locations is presented in Figure 5.1.3(a). Sediment concentration data for trace metals and iron are presented in Figures 5.1.3(b) and 5.1.3(c), respectively. Sediment concentrations of iron were generally three orders of magnitude greater than all trace metals. Manganese is typically found in two oxidation states; divalent (Mn (II)) and trivalent/tetravalent (Mn(III/IV)) as a (hydr)oxide compound. Mn (III/IV) (hydr)oxides are the only known naturally occurring oxidant for facilitating the conversion of Cr (III) to Cr (VI). Of the two species, Mn (II) is predominantly found in Baltimore Harbor sediments due to the presence of Mn-reducing microbial organisms. Total chromium sediment concentrations from all stations exceeded the effects range low (ERL) criteria of 81 mg/kg and from four stations exceeded the ERM of 370 mg/kg (Wadhawan 2012).

In all sediment samples, AVS levels exceeded the SEM concentration for total metals, indicating a reducing environment, where Cr (III), the relatively non-toxic species at levels typically found within the environment, is the predominant form of chromium found in sediments. Therefore, any toxicity present in the existing sediments is not due to chromium. AVS/SEM concentrations for total metals are presented in Figure 5.1.3(d) (Wadhawan 2012).



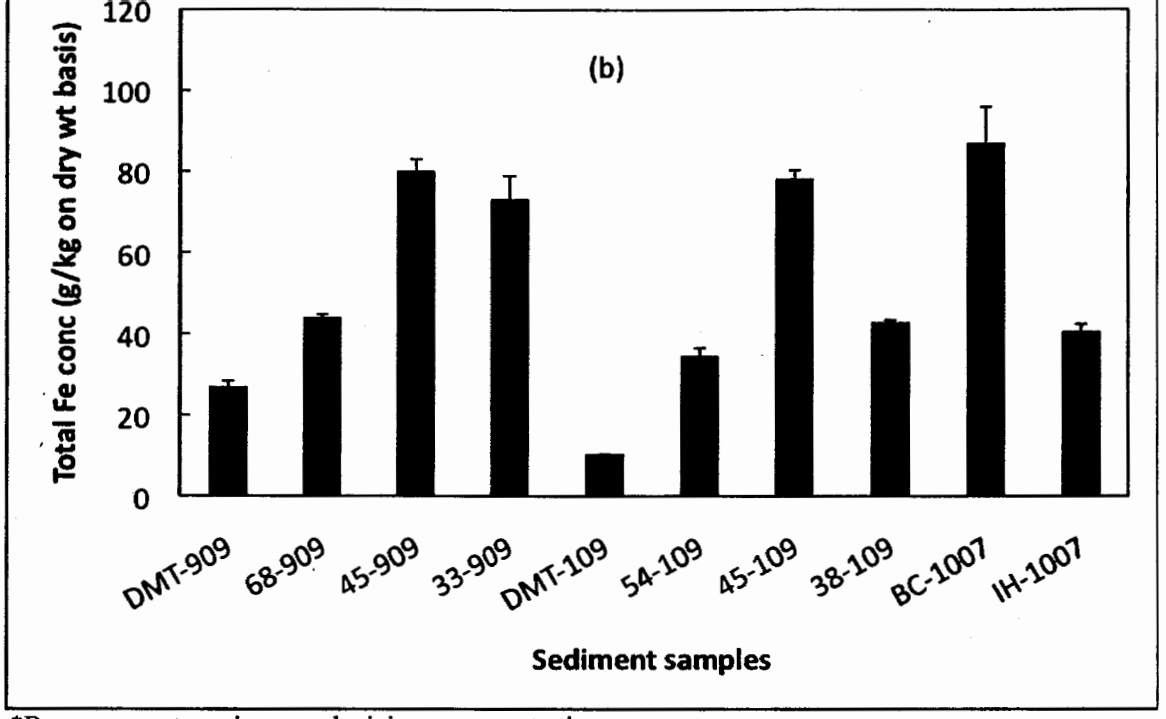
The objective of this study was to determine if Cr (VI) reduction to Cr (III) is the dominant and ongoing process in Baltimore Harbor sediments and whether the presence of oxygen will alter biogeochemical conditions facilitating the oxidation of Cr (III). Suspensions of sediments collected from stations throughout the Baltimore Harbor were employed in batch reaction experiments under anaerobic and aerobic conditions with additions of chromium to evaluate Cr (III) oxidation and Cr (VI) reoccurrence (Wadhawan 2012).

For an evaluation of Cr (III) oxidation, under anaerobic conditions, which is the predominant state of in-situ sediments, additions of Cr (III) to sediment suspensions resulted in no formation of Cr (VI) in multiple batch experiments. Under aerobic conditions, in which the sediment suspension was then oxygenated, Cr (VI) formation occurred in several sediment suspensions. Oxidation of Cr (III) additions ranged between 0.2 and 3 % in all sediment suspensions except for station DMT in which 70 % of available Cr (III) was oxidized. Cr (VI) concentrations over the duration of the batch experiments are presented in Figure 5.1.3(e) (Wadhawan 2012).



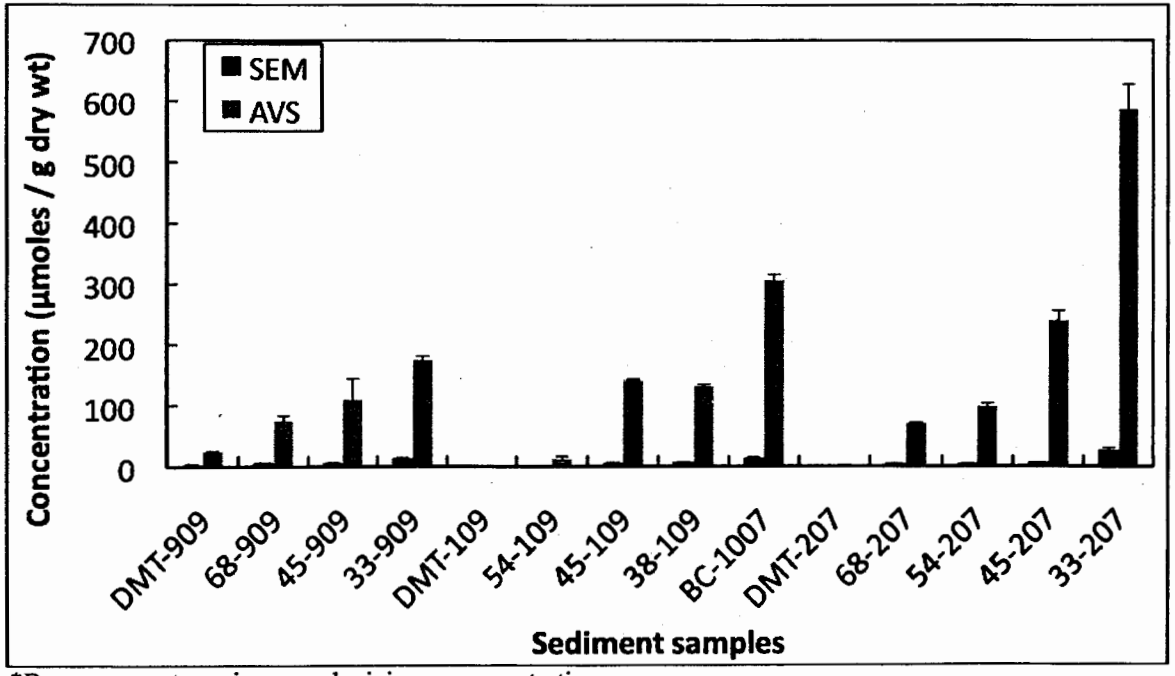
*Bars represent maximum and minimum concentrations

Figure 5.1.3(b): Sediment Concentration Data (Trace Metals)



*Bars represent maximum and minimum concentrations

Figure 5.1.3(c): Sediment Concentration Data (Fe)



*Bars represent maximum and minimum concentrations

Figure 5.1.3(d): AVS/SEM Sediment Concentrations

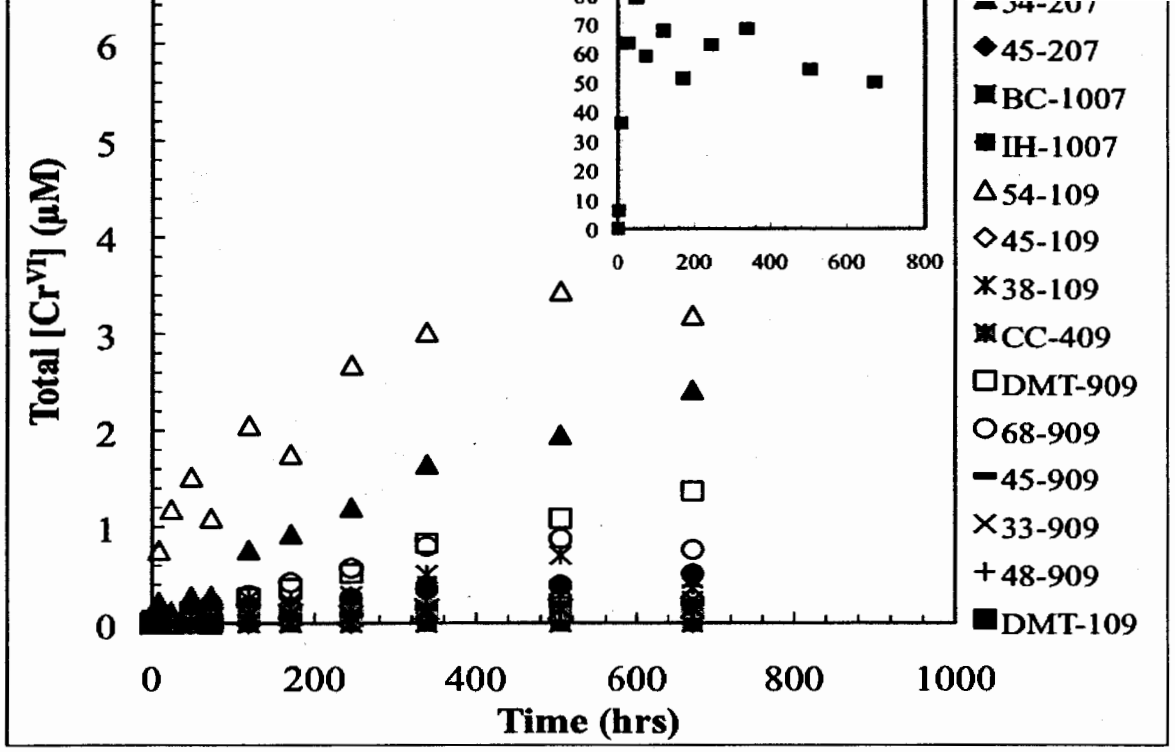


Figure 5.1.3(e): Cr (VI) Concentration vs. Time (Cr (III) suspension under Aerobic conditions)

Batch experiments run under aerobic conditions without chromium additions found oxidation of background Cr (III) to be insignificant as Cr (VI) formation did not occur, indicating that Cr (VI) was only formed from the oxidation of the Cr (III) additions. Formation of Cr (VI) occurred due to the oxygenation of the sediment suspensions which reduced concentrations of AVS and Fe (II), thus lowering the overall reducing capacity and facilitated the formation of Mn (III/IV) (hydr)oxide compounds necessary for oxidation of Cr (III) (Wadhawan 2012).

For an evaluation of Cr (VI) reoccurrence, sediment suspensions were dosed with Cr (VI) under anaerobic conditions allowing complete reduction of Cr (VI) to Cr (III) followed by aeration of the suspension to evaluate the secondary formation of Cr (VI) in multiple batch experiments. Cr (VI) formation or reoccurrence occurred in all batch experiments with concentrations ranging between 1 and 15 % of the original Cr (VI) addition. Cr (VI) concentrations over the duration of the batch experiments are presented in Figure 5.1.3(f). Cr (VI) formation reached a maximum concentration well below the available amount of oxidizable Cr (III) and either maintained a plateau or declined. The reaction may have ceased due to limited availability of Mn (III/IV) (hydr)oxides. The effect of "aging" on Cr (III) oxidation was investigated in these experiments by increasing the time interval between aeration of the sediment suspension following complete reduction of Cr (VI) additions to Cr (III). Cr (VI) concentrations over the duration of the experiments following aging (4.5 hours, 1 day and 5 days) are presented in Figure 5.1.3(g). Cr (VI) formation was delayed as aging time was increased and the rate of Cr (VI) formation and Cr

adsorption of organic matter and metal ions present in the sediment which limit accessibility for oxidation by Mn (III/IV) (hydr)oxides, thus Cr (III) reactivity will decrease over time as long as reducing conditions remain in sediments (Wadhawan 2012).

While oxidation of Cr (III) to Cr (VI) may occur from oxygenation during sediment resuspension due to dredging, flood events, and bioturbation, the potential for Cr (VI) formation is dependent on the reactivity of existing Cr (III) in the sediments and its long-term persistence is governed by sediment reducing capacity. Cr (III) present in Baltimore Harbor sediments will remain relatively inert as oxidation reactivity is minimized due to prolonged anoxia supporting a sulfide rich environment. Any Cr (VI) formed during periods of resuspension will not persist as the excess reductant capacity in the form of sulfide and Fe (II) will facilitate the complete conversion of Cr (VI) to Cr (III) (Wadhawan 2012). Considering all these factors, it is understandable that no significant Cr (VI) was detected in the 'in-situ' Baltimore Harbor sediments and that this will remain so in the future as these conditions persist (Wadhawan 2012).

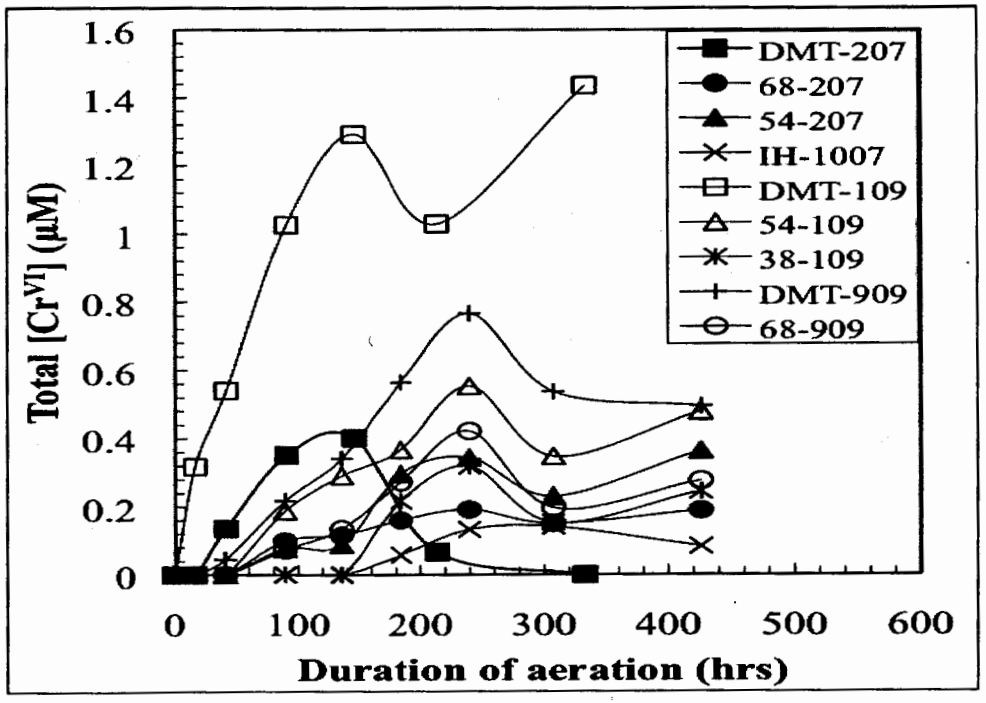


Figure 5.1.3(f): Cr (VI) Concentration vs. Time (Complete Reduction of Cr (VI) suspension to Cr (III) followed by aeration)

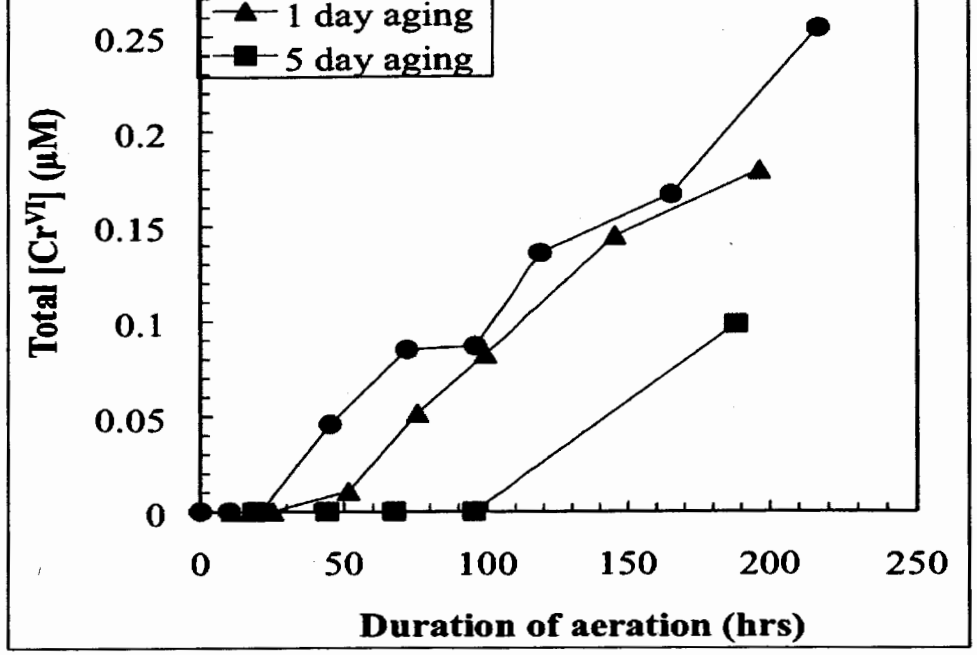


Figure 5.1.3(g): Cr (VI) Concentration vs. Time (Complete Reduction of Cr (VI) suspension to Cr (III) followed by aging (4.5 hr, 1 day, and 5 day) and subsequent aeration)

5.2 Data Evaluation and Screening Level Human Health and Ecological Risk Assessment for Bear Creek Sediments

EPA completed a "Data Evaluation and Screening Level Human Health and Ecological Risk Assessment for Bear Creek Sediment" study in October 2011. Surficial sediment samples were collected at ten stations throughout Bear Creek in 2009 by the Chesapeake Bay Foundation (CBF). This information was provided to EPA and MDE for assessment purposes. The samples were analyzed for select inorganics and PAHs including total chromium and Cr (VI). A map displaying the sediment station locations is presented in Figure 5.2.1. The map also displays historical station locations sampled in 1996 under the "Spatial Mapping of Sedimentary Contaminants in the Baltimore/Patapsco River/Back River System (BSM)" study conducted by Baker *et al.* Information from this historical study was applied in this data evaluation (EPA 2011).

Total chromium sediment concentrations for all samples ranged between 27.7 mg/kg and 705.0 mg/kg with an average of 225.6 mg/kg. No Cr (VI) was detected in any sediment sample with an average method detection level of 1.39 mg/kg. A comparison of total chromium sediment concentrations and the SQG Probable Effects Level (PEL) of 160 mg/kg for Total Cr, developed by MacDonald *et al.* (1996) resulted in four exceedances. No SQG has been established for Cr (VI). Sediment concentration data for total chromium and Cr (VI) and the PEL is presented in Table 5.2.1 (EPA 2011).

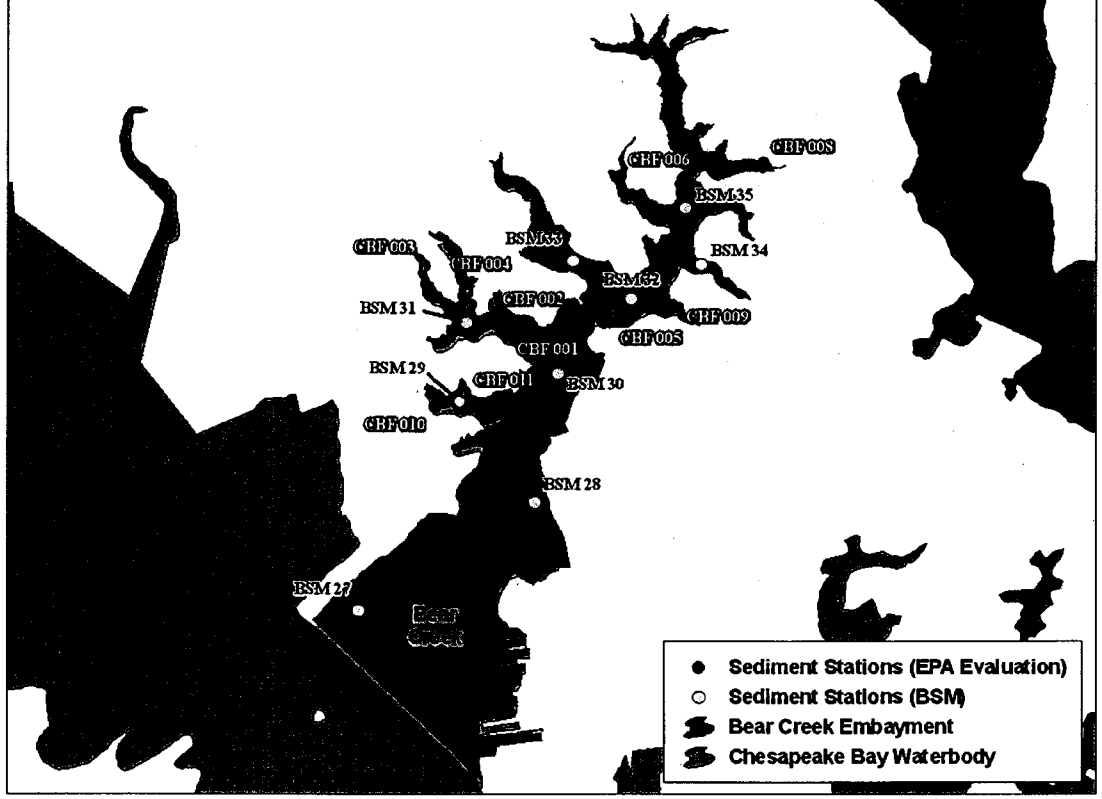


Figure 5.2.1: Bear Creek Sediment Stations (EPA Data Evaluation and BSM)

Table 5.2.1: Total Cr and Cr (VI) Sediment Concentration Data (EPA Data Evaluation)

Station	Total Cr (mg/kg)	Cr (VI) (mg/kg)	PEL (mg/kg)
CBF 001	**705.0***	ND (2.8)**	160
CBF 002	27.7	ND (0.8)	160
CBF 003	**181.0**	ND (1.7)	160
CBF 004	25.6	ND (0.8)	160
CBF 005	30.7	ND (0.6)	160
CBF 006	**265.0**	ND (2.2)	160
CBF 008	81.9	ND(1.2)	160
CBF 009	**175.0**	ND (1.0)	160
CBF 010	128.0	ND (1.1)	160
CBF 011	636.0	ND (1.7)	160
Average	**225.6**	**ND**	-

*Sediment concentrations which exceed the PEL are presented in bold

within the sediment where Cr (III), the relatively non-toxic species at levels typically found within the environment, will be the predominant form of chromium. Also as Cr (VI) was not detected in sediment concentrations, it would not be expected for Cr (VI) to be elevated in pore water. The previous studies summarized in this report establish that Cr (VI) is not present in pore water at levels that exceed criterion supporting the aquatic life designated use. Therefore any toxicity found within the sediments of Bear Creek is not due to the presence of chromium (EPA 2011).

A comparison of current sediment concentrations for total chromium collected under this study and sediments collected from Bear Creek in 1996 under the BSM study found that the average total chromium sediment concentrations has declined by 77%. The average total chromium sediment concentrations for samples collected in 1996 and 2009, were 986.1 mg/kg and 225.6, respectively. The sediment concentration data for all monitoring stations from the BSM study is presented in Table 5.2.2. The locations of the monitoring stations were presented previously in Figure 5.2.1. Sediment concentrations for total chromium in Bear Creek have declined significantly since 1996 and should continue to do so over time as freshly deposited sediments bury historically contaminated sediments (EPA 2011).

Table 5.2.2: 1996 Total Chromium Sediment Concentration Data (BSM)

Station	Total Chromium (mg/kg)
BSM 27	51.9
BSM 28	1831.1
BSM 29	1536.4
BSM 30	1046.7
BSM 31	1141.7
BSM 32	1027.5
BSM 33	719.4
BSM 34	678.5
BSM 35	841.3
Average	**986.1**

An Ecological Risk Assessment (ERA) of Dundalk Marine Terminal (DMT) located within the Baltimore Harbor was completed in September 2009 in compliance with a Consent Decree between the Maryland Port Administration (MPA), MDE, and Honeywell International Inc. DMT is a significant source of chromium to adjacent waters in the Baltimore Harbor as it was constructed over a land mass containing a large amount of chromium ore processing residue (COPR) fill material. The objective of the ERA was to determine whether sources of chromium from DMT pose an unacceptable risk to the ecological health of the system. While DMT is not located within Northwest Branch or Bear Creek, the site is representative of environmental conditions found throughout the Baltimore Harbor and provides supporting evidence that chromium is not a source of toxicity within these sediments. The location of DMT within the Baltimore Harbor is displayed in Figure 5.3.1 (CH2M HILL 2009).

As stated previously within the document, reducing conditions within sediment facilitate the conversion of Cr (VI) to Cr (III) in anoxic estuarine environments. Sediments with elevated levels of sulfides and Fe (II) provide a reducing environment where Cr (III) is the predominant species of chromium. Under this ERA, the toxicity of Cr was evaluated based on a comparison of Cr (VI) and total chromium concentrations in pore water and surface water to USEPA Nationally Recommended Water Quality Criteria (NRWQC), Maryland's adopted numeric criterion (CH2M HILL 2009).

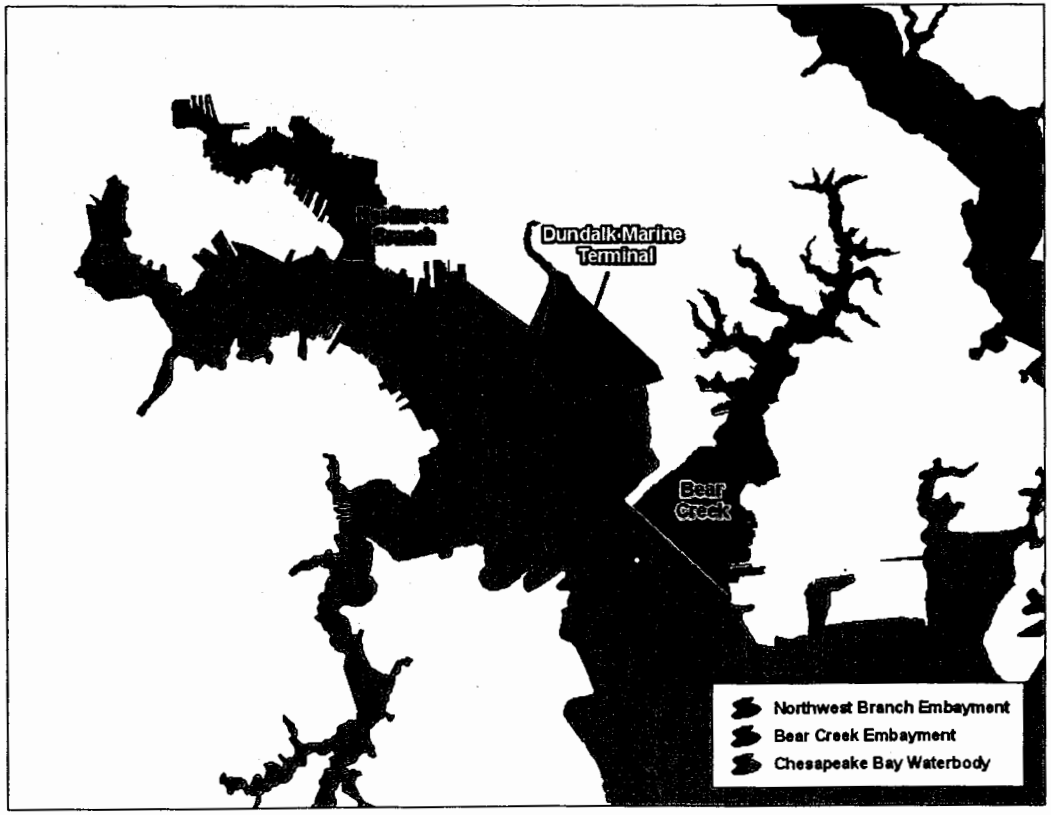


Figure 5.3.1: Location of Dundalk Marine Terminal

presented in Figure 5.3.2. Cr (VI) and total chromium were analyzed in all pore water and surface water samples. Only total chromium was analyzed in sediment samples, as Cr (VI), if present, will predominantly partition to pore water, as it is highly soluble. Therefore, pore water analysis is the most appropriate method for quantifying Cr (VI) associated with sediments (CH2M HILL 2009).

Figure 5.3.2: Dundalk Marine Terminal Water Quality Stations

Total chromium concentrations in pore water ranged from a detection level of 2.3 µg/L to 16.2 µg/L. Cr (VI) was not detected in pore water in any sample taken from DMT. The detection level was 5 µg/L. Total chromium and Cr (VI) concentrations in pore water were well below the saltwater aquatic life chronic criterion of 50 µg/L. Total chromium and Cr (VI) concentrations in surface water ranged from a detection level of 2.3 µg/L to 37.6 µg/L and a detection level of 5 µg/L to 34.9 µg/L, respectively. Cr (VI) was not detected in 97 percent of surface water samples analyzed, and for those samples that were detected; concentrations were well below the saltwater aquatic life chronic criterion. Surface water and pore water concentrations of total chromium and Cr (VI) are displayed in Table A-1 and Table A-2 of Appendix A, respectively (CH2M HILL 2009).

A-3 of Appendix A. While sediment concentrations of total chromium exceeded the ERM of 370 mg/kg, this is not an indication of toxicity if the predominant form of chromium in sediment is Cr (III), the relatively non-toxic species at levels typically found within the environment. Geochemical parameters were analyzed to determine whether conditions within the sediment provide a reducing environment supporting the conversion of Cr (VI) to Cr (III). These include Fe (II), divalent manganese (Mn (II)), TOC, sulfide, and AVS/SEM. Concentrations of geochemical parameters and AVS/SEM are presented in Table A-3 and A-4 of Appendix A, respectively. Levels of these geochemical parameters establish that conditions are favorable for the presence of Cr (III) over Cr (VI). Molar concentrations of AVS and Fe were greater than the SEM molar concentrations for total metals in all analyses giving further indication that Cr (III) is the predominant species. Cr (III) in sediments is unlikely to oxidize to Cr (VI) in the future as geochemical conditions for this process are not supported (CH2M HILL 2009).

As all measured concentrations of total chromium and Cr (VI) in pore water and surface water were below criteria, and reducing conditions within the sediment support the conversion of Cr (VI) to Cr (III), chromium does not pose a risk to aquatic life and is therefore not a source of toxicity in the water column or sediment (CH2M HILL 2009).

Based on the evaluation presented in this report, it has been determined that chromium is not a source of toxicity to aquatic life in the water column or sediments of the Northwest Branch and Bear Creek tidal segments. Therefore, the protection of the aquatic life designated use is not impaired by chromium.

MDE originally completed a WQA in 2004 in order to remove the chromium impairment listings in sediments for the Northwest Branch and Bear Creek portions of the Baltimore Harbor from Maryland's Integrated Report. The WQA established that the sediments are composed primarily of Cr (III), the relatively non-toxic species, at levels typically found within the environment. This indicates that any existing toxicity within the sediments is not due to the presence of chromium. While the listings are for sediment only, chromium contamination within the sediment has the potential to transport into the water column through resuspension and diffusion across the sediment-water interface. An analysis of chromium in the water column found that concentrations of Cr (III) and Cr (VI) were all well below the criterion. Therefore the water column and sediments are not impaired for chromium and the protection of aquatic life designated use is supported within the water column and sediments.

Following review of the chromium WQA, EPA stated that they supported the findings of the original study but chose to defer a delisting decision contingent upon the results of a TIE study underway at the time which could potentially identify a chemical contaminant responsible for impairing the benthic community in the Baltimore Harbor. The results of the TIE study were inconclusive regarding the toxicity of metals in Baltimore Harbor sediments; therefore, EPA did not approve the delisting decision supported by the original chromium WQA.

In order to assist MDE in addressing the chromium impairment listings, JHU CTFR conducted several studies investigating the relationship between toxicity and the exposure of chromium to benthic organisms, sediment ingestion as a pathway of toxicity, and the stability of Cr (III) under oxygenation in the sediments of Baltimore Harbor.

The sediment toxicity study established that chromium is not responsible for observed toxicity in Baltimore Harbor sediments at environmentally relevant levels. The findings of the sediment ingestion study demonstrated that Cr (III) is biologically unavailable to sediment dwelling organisms and levels of Cr (III) much greater than those found in Baltimore Harbor sediments are not toxic to benthic life. The sediment oxygenation study demonstrated that there is very little potential for oxidation of Cr (III) to occur in Baltimore Harbor sediments and if Cr (VI) does form it will not persist due to excess reducing capacity within the sediments

In addition to the studies conducted by JHU CTFR, an ERA of DMT and EPA Data Evaluation of Bear Creek sediments provided additional support that chromium is not a source of toxicity within Baltimore Harbor sediments. Sediment concentrations of total chromium in Bear Creek have also reduced by 77% between 1996 and 2009 indicating that sources of chromium within the Baltimore Harbor watershed are declining.

Based on the cumulative findings of all studies presented in this document, including the original

Barring the receipt of contradictory data, this report will be used to support the revision of the 2012 Integrated Report Chromium listings for Northwest Branch and Bear Creek from Category 5 ("waterbody is impaired, does not attain the water quality standard, and a TMDL is required") to Category 2 ("waterbody is meeting some [in this case chromium related] water quality standards, but with insufficient data to assess all impairment") when MDE proposes the revision of Maryland's Integrated Report. Although the tidal waters of Northwest Branch and Bear Creek do not display signs of chromium impairment to aquatic life in the water column or sediment, the State reserves the right to require future controls if evidence suggests that chromium from the watershed is contributing to downstream water quality problems.

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Table A-1: Total Cr and Cr (VI) Surface Water Concentration Data (ERA DMT)

Station	Quarter	Date	Surface water Concentration (µg/L)		Station	Quarter	Date	Surface water Concentration (µg/L)	
			Total Cr	Cr (VI)				Total Cr	Cr (VI)
A1	Q1	May-07	2.3	5	E2	Q4-Dup	Feb-08	2.3	5
A1	Q2	Aug-07	2.3	5	E2	Q4	Feb-08	2.7	5
A1	Q3	Dec-07	5.6	5	E2	Q4	Feb-08	2.3	5
A1	Q4	Feb-08	2.3	5	E3	Q1	May-07	2.3	5
A1	Q4	Feb-08	2.3	5	E3	Q1	May-07	2.3	5
A2	Q1	May-07	2.3	5	E3	Q1	May-07	2.3	5
A2	Q1-Dup	May-07	2.5	5	E3	Q2	Aug-07	2.3	5
A2	Q2	Aug-07	2.3	5	E3	Q2	Aug-07	3.1	5
A2	Q2	Aug-07	2.3	5	E3	Q2	Aug-07	2.3	5
A2	Q3	Dec-07	2.3	5	E4	Q1	May-07	3.3	5
A2	Q4	Feb-08	2.4	5	E4	Q1	May-07	3.2	5
A3	Q1	May-07	2.3	5	E4	Q1	May-07	2.3	5
A3	Q2	Aug-07	2.3	5	E4	Q2	Aug-07	2.3	5
A3	Q3	Dec-07	2.3	5	E4	Q2	Aug-07	2.4	5
A3	Q4	Feb-08	2.3	5	E4	Q2	Aug-07	2.3	5
A3	Q4-Dup	Feb-08	2.3	5	E4	Q3	Dec-07	2.3	5
A4	Q1	May-07	2.3	5	E4	Q3	Dec-07	3.6	5
A4	Q2	Aug-07	2.3	5	E4	Q3	Dec-07	2.3	5
A4	Q2	Aug-07	2.3	5	E4	Q4	Feb-08	2.3	5
A4	Q3	Dec-07	2.3	5	E4	Q4	Feb-08	2.3	5
A4	Q4	Feb-08	2.3	5	E4	Q4	Feb-08	2.8	5
B1	Q1	May-07	2.3	5	F1	Q1	May-07	2.3	5
B1	Q2	Aug-07	3.8	5	F1	Q1	May-07	2.3	5
B1	Q2	Aug-07	5.2	5	F1	Q1	May-07	2.3	5
B1	Q3	Dec-07	2.3	5	F1	Q2	Aug-07	2.3	5
B1	Q3	Dec-07	-	-	F1	Q2	Aug-07	2.3	5
B1	Q3-Dup	Dec-07	-	-	F1	Q2	Aug-07	2.3	5
B1	Q3	Dec-07	2.3	5	F1	Q2-Dup	Aug-07	2.3	5
B1	Q4	Feb-08	2.3	5	F2	Q1	May-07	2.3	5
B1	Q4	Feb-08	4.2	5	F2	Q1	May-07	2.3	5
B2	Q1	May-07	2.3	5	F2	Q1	May-07	2.3	5

Station	Quarter	Date	(µg/L)		Station	Quarter	Date	(µg/L)	
			Total Cr	Cr (VI)				Total Cr	Cr (VI)
B2	Q2	Aug-07	5.7	5	F2	Q2	Aug-07	2.3	5
B2	Q2	Aug-07	7.3	5	F2	Q2	Aug-07	2.3	5
B2	Q3	Dec-07	2.3	5	F2	Q3	Dec-07	2.3	5
B2	Q3	Dec-07	-	-	F2	Q3	Dec-07	2.3	5
B2	Q3	Dec-07	3.3	5	F2	Q3	Dec-07	2.3	5
B2	Q4	Feb-08	2.3	5	F2	Q4	Feb-08	2.3	5
B2	Q4	Feb-08	2.3	5	F2	Q4	Feb-08	2.3	5
B3	Q1	May-07	2.3	5	F2	Q4	Feb-08	2.3	5
B3	Q1	May-07	2.3	5	F3	Q1	May-07	2.3	5
B3	Q2	Aug-07	6.1	6	F3	Q1	May-07	2.3	5
B3	Q2	Aug-07	6	5	F3	Q1	May-07	2.3	5
B3	Q3	Dec-07	2.3	5	F3	Q2	Aug-07	2.3	5
B3	Q3	Dec-07	2.3	5	F3	Q2	Aug-07	2.3	5
B3	Q3	Dec-07	2.3	5	F3	Q2	Aug-07	2.3	5
B3	Q4	Feb-08	2.3	5	F4	Q1	May-07	2.3	5
B3	Q4	Feb-08	2.3	5	F4	Q1	May-07	2.3	5
B4	Q1	May-07	2.3	5	F4	Q1-Dup	May-07	2.3	5
B4	Q1	May-07	2.3	5	F4	Q1	May-07	2.3	5
B4	Q1-Dup	May-07	2.3	5	F4	Q2	Aug-07	2.3	5
B4	Q2	Aug-07	29.7	34.9	F4	Q2	Aug-07	2.3	5
B4	Q2	Aug-07	26	32.9	F4	Q2	Aug-07	2.3	5
B4	Q2-Dup	Aug-07	30.8	32	F4	Q3	Dec-07	2.3	5
B4	Q3	Dec-07	2.3	5	F4	Q3	Dec-07	2.3	5
B4	Q3	Dec-07	3.1	5	F4	Q3	Dec-07	2.3	5
B4	Q3	Dec-07	2.3	5	F4	Q4	Feb-08	2.3	5
B4	Q4	Feb-08	2.3	5	F4	Q4	Feb-08	2.3	5
B4	Q4	Feb-08	2.3	5	F4	Q4	Feb-08	2.3	5
B4	Q4	Feb-08	2.3	5	G1	Q1	May-07	2.3	5
B5	Q4	Feb-08	2.3	5	G1	Q1	May-07	2.3	5
B5	Q4	Feb-08	2.3	5	G1	Q1	May-07	2.3	5
C1	Q1	May-07	2.3	5	G1	Q2	Aug-07	2.3	5
C1	Q2	Aug-07	7.6	5	G1	Q2	Aug-07	2.3	5
C1	Q2	Aug-07	8.4	5	G1	Q2	Aug-07	2.3	5
C1	Q2-Dup	Aug-07	7.9	5	G2	Q1	May-07	2.3	5
C1	Q3	Dec-07	6.6	7	G2	Q1	May-07	2.3	5
C1	Q3-Dup	Dec-07	9.4	6.9	G2	Q1	May-07	2.3	5

Station	Quarter	Date	Concentration (µg/L)		Station	Quarter	Date	Concentration (µg/L)	
			Total Cr	Cr (VI)				Total Cr	Cr (VI)
C2	Q1	May-07	2.3	5	G2	Q2	Aug-07	2.3	5
C2	Q1	May-07	2.3	5	G2	Q2	Aug-07	2.3	5
C2	Q2	Aug-07	4.2	5	G2	Q3	Dec-07	2.3	5
C2	Q2	Aug-07	5.6	5	G2	Q3	Dec-07	2.3	5
C2	Q3	Dec-07	2.3	5	G2	Q3	Dec-07	2.3	5
C2	Q3	Dec-07	-	-	G2	Q4	Feb-08	2.3	5
C2	Q3	Dec-07	2.3	5	G2	Q4	Feb-08	2.3	5
C2	Q4	Feb-08	2.3	5	G2	Q4	Feb-08	2.6	5
C3	Q1	May-07	2.3	5	G3	Q1	May-07	2.3	5
C3	Q1	May-07	2.3	5	G3	Q1	May-07	2.3	5
C3	Q2	Aug-07	5.6	5	G3	Q1	May-07	2.3	5
C3	Q2	Aug-07	4.5	5	G3	Q2	Aug-07	2.3	5
C3	Q2	Aug-07	5.8	5	G3	Q2	Aug-07	2.3	5
C3	Q3	Dec-07	2.9	5	G3	Q2	Aug-07	2.3	5
C3	Q3	Dec-07	2.3	5	G4	Q1	May-07	2.3	5
C3	Q4	Feb-08	2.3	5	G4	Q1	May-07	2.3	5
C3	Q4	Feb-08	2.3	5	G4	Q1	May-07	2.3	5
C4	Q1	May-07	2.3	5	G4	Q2	Aug-07	2.3	5
C4	Q1	May-07	2.3	5	G4	Q2	Aug-07	2.3	5
C4	Q2	Aug-07	5.5	5	G4	Q2	Aug-07	2.3	5
C4	Q2	Aug-07	6.2	5	G4	Q3	Dec-07	2.3	5
C4	Q2	Aug-07	2.6	5	G4	Q3	Dec-07	2.3	5
C4	Q3	Dec-07	2.3	5	G4	Q3	Dec-07	2.3	5
C4	Q3-Dup	Dec-07	2.3	5	G4	Q4	Feb-08	2.3	5
C4	Q3	Dec-07	2.3	5	G4	Q4	Feb-08	2.3	5
C4	Q4	Feb-08	2.3	5	G4	Q4	Feb-08	2.3	5
C4	Q4	Feb-08	2.3	5	H1	Q1	May-07	2.3	5
D1	Q1	May-07	2.3	5	H1	Q1	May-07	2.3	5
D1	Q1	May-07	2.3	5	H1	Q1	May-07	2.3	5
D1	Q1	May-07	2.3	5	H1	Q2	Aug-07	2.3	5
D1	Q2	Aug-07	2.3	5	H1	Q2	Aug-07	2.3	5
D1	Q2	Aug-07	2.3	5	H1	Q2	Aug-07	2.3	5
D1	Q2	Aug-07	2.3	5	H1	Q3	Dec-07	3.6	5
D1	Q3	Dec-07	6.5	5	H1	Q3	Dec-07	2.7	5
D1	Q3	Dec-07	4.8	5	H1	Q3-Dup	Dec-07	2.6	5
D1	Q3	Dec-07	2.5	5	H1	Q3	Dec-07	2.3	5

Station	Quarter	Date	(µg/L)		Station	Quarter	Date	(µg/L)	
			Total Cr	Cr (VI)				Total Cr	Cr (VI)
D1	Q4	Feb-08	2.3	5	H1	Q4	Feb-08	2.3	5
D1	Q4	Feb-08	2.7	5	H1	Q4	Feb-08	2.3	5
D2	Q1	May-07	2.3	5	H2	Q1	May-07	2.3	5
D2	Q1	May-07	2.3	5	H2	Q1	May-07	2.3	5
D2	Q1	May-07	2.3	5	H2	Q1	May-07	2.3	5
D2	Q2	Aug-07	2.3	5	H2	Q2	Aug-07	2.3	5
D2	Q2	Aug-07	2.3	5	H2	Q2	Aug-07	2.3	5
D2	Q2	Aug-07	2.3	5	H2	Q2	Aug-07	2.3	5
D2	Q3	Dec-07	2.3	5	H3	Q1	May-07	2.3	5
D2	Q3	Dec-07	2.3	5	H3	Q1	May-07	2.3	5
D2	Q3	Dec-07	2.5	5	H3	Q1	May-07	2.3	5
D2	Q4	Feb-08	2.8	5	H3	Q2	Aug-07	2.3	5
D2	Q4	Feb-08	2.3	5	H3	Q2	Aug-07	2.3	5
D2	Q4	Feb-08	2.3	5	H3	Q2	Aug-07	2.3	5
D3	Q1	May-07	2.3	5	H4	Q1	May-07	2.3	5
D3	Q1	May-07	2.3	5	H4	Q1	May-07	2.3	5
D3	Q1	May-07	2.3	5	H4	Q1	May-07	2.3	5
D3	Q2	Aug-07	2.3	5	H4	Q2	Aug-07	2.3	5
D3	Q2	Aug-07	3.2	5	H4	Q2	Aug-07	2.3	5
D3	Q2	Aug-07	2.3	5	H4	Q2	Aug-07	2.3	5
D3	Q3	Dec-07	2.3	5	H4	Q3	Dec-07	2.3	5
D3	Q3	Dec-07	2.3	5	H4	Q3	Dec-07	2.3	5
D3	Q3	Dec-07	2.3	5	H4	Q3	Dec-07	2.3	5
D3	Q4	Feb-08	9.4	6.3	H4	Q4	Feb-08	2.3	5
D3	Q4-Dup	Feb-08	8.9	6.7	H4	Q4	Feb-08	2.3	5
D3	Q4	Feb-08	2.3	5	H4	Q4	Feb-08	2.3	5
D3	Q4	Feb-08	2.3	5	I1	Q1	May-07	2.3	5
D4	Q1	May-07	2.3	5	I1	Q2	Aug-07	2.3	5
D4	Q1	May-07	2.3	5	I1	Q2	Aug-07	2.3	5
D4	Q1-Dup	May-07	2.3	5	I1	Q3	Dec-07	2.3	5
D4	Q1	May-07	2.3	5	I1	Q4	Feb-08	2.3	5
D4	Q2	Aug-07	2.3	5	I1	Q4-Dup	Feb-08	2.3	5
D4	Q2	Aug-07	2.3	5	I2	Q1	May-07	2.3	5
D4	Q2	Aug-07	2.3	5	I2	Q1	May-07	2.3	5
D4	Q3	Dec-07	2.7	5	I2	Q2	Aug-07	2.3	5
D4	Q3	Dec-07	4.5	5	I2	Q2	Aug-07	2.3	5
D4	Q3-Dup	Dec-07	2.9	5	I2	Q2	Aug-07	2.3	5

Station	Quarter	Date	Concentration (µg/L)		Station	Quarter	Date	Concentration (µg/L)	
			Total Cr	Cr (VI)				Total Cr	Cr (VI)
D4	Q4	Feb-08	2.3	5	I2	Q3	Dec-07	2.9	5
D4	Q4	Feb-08	2.3	5	I2	Q3	Dec-07	2.3	5
D4	Q4	Feb-08	2.3	5	I2	Q4	Feb-08	2.3	5
E1	Q1	May-07	2.3	5	I2	Q4	Feb-08	2.3	5
E1	Q1	May-07	2.3	5	I3	Q1	May-07	2.3	5
E1	Q1	May-07	2.3	5	I3	Q1	May-07	2.3	5
E1	Q1-Dup	May-07	2.3	5	I3	Q1	May-07	2.3	5
E1	Q2	Aug-07	2.3	5	I3	Q2	Aug-07	2.3	5
E1	Q2	Aug-07	21.3	25.7	I3	Q2	Aug-07	2.3	5
E1	Q2	Aug-07	2.3	5	I3	Q2	Aug-07	2.3	5
E1	Q3	Dec-07	37.6	30.4	I3	Q3	Dec-07	2.3	5
E1	Q3	Dec-07	5.5	5	I3	Q3	Dec-07	2.3	5
E1	Q3	Dec-07	2.7	5	I3	Q4	Feb-08	2.3	5
E1	Q4	Feb-08	6.1	8.1	I3	Q4	Feb-08	2.3	5
E1	Q4	Feb-08	2.4	5	I4	Q1	May-07	2.3	5
E1	Q4	Feb-08	2.3	5	I4	Q1	May-07	2.3	5
E2	Q1	May-07	2.3	5	I4	Q2	Aug-07	2.3	5
E2	Q1	May-07	2.3	5	I4	Q2	Aug-07	2.3	5
E2	Q1	May-07	2.3	5	I4	Q2	Aug-07	2.3	5
E2	Q2	Aug-07	2.3	5	I4	Q3	Dec-07	2.3	5
E2	Q2	Aug-07	2.3	5	I4	Q3	Dec-07	2.3	5
E2	Q2	Aug-07	2.3	5	I4	Q4	Feb-08	2.3	5
E2	Q3	Dec-07	10.2	11	I4	Q4	Feb-08	2.3	5
E2	Q3	Dec-07	3	5	J1	Q4	Feb-08	2.3	5
E2	Q3	Dec-07	2.3	5	J2	Q4	Feb-08	2.3	5
E2	Q4	Feb-08	2.3	5	J3	Q4	Feb-08	2.3	5
					J4	Q4	Feb-08	2.3	5

Station	Quarter	Date	Pore water Concentration (µg/L)		Station	Quarter	Date	Pore water Concentration (µg/L)	
			Total Cr	Cr (VI)				Total Cr	Cr (VI)
A1	Q1	May-07	2.3	5	E1	Q2	Aug-07	6.5	5
A1	Q2	Aug-07	2.3	5	E1	Q3	Dec-07	4	5
A1	Q3	Dec-07	2.3	5	E1	Q4	Feb-08	2.3	5
A1	Q4	Feb-08	2.3	5	E2	Q1	May-07	2.3	5
A2	Q1	May-07	2.3	5	E2	Q2	Aug-07	12.2	5
A2	Q2	Aug-07	-	-	E2	Q3	Dec-07	8.1	5
A2	Q3	Dec-07	4.3	5	E2	Q4	Feb-08	5.7	5
A2	Q4	Feb-08	2.3	5	E3	Q1	May-07	3.2	5
A3	Q1	May-07	2.3	5	E3	Q2	Aug-07	13.5	5
A3	Q2	Aug-07	-	-	E4	Q1	May-07	2.3	5
A3	Q3	Dec-07	3.1	5	E4	Q2	Aug-07	2.3	5
A3	Q4	Feb-08	2.9	5	E4	Q3	Dec-07	2.3	5
A4	Q1	May-07	-	-	E4	Q4	Feb-08	2.3	5
A4	Q2	Aug-07	-	-	F1	Q1	May-07	3	5
A4	Q3	Dec-07	3.2	5	F1	Q2	Aug-07	7.4	5
A4	Q4	Feb-08	2.3	5	F2	Q1	May-07	2.3	5
B1	Q1	May-07	2.3	5	F2	Q2	Aug-07	3.2	5
B1	Q2	Aug-07	3.5	5	F2	Q3	Dec-07	3.5	5
B1	Q3	Dec-07	2.3	5	F2	Q4	Feb-08	6.2	5
B1	Q4	Feb-08	2.3	5	F3	Q1	May-07	4.7	5
B2	Q1	May-07	2.3	5	F3	Q2	Aug-07	10.1	5
B2	Q2	Aug-07	2.3	5	F3	Q2-Dup	Aug-07	9.1	5
B2	Q3	Dec-07	2.3	5	F4	Q1	May-07	3.2	5
B2	Q4	Feb-08	2.3	5	F4	Q2	Aug-07	8.2	5
B3	Q1	May-07	2.3	5	F4	Q3	Dec-07	2.3	5
B3	Q2	Aug-07	2.3	5	F4	Q4	Feb-08	5.7	5
B3	Q3	Dec-07	2.3	5	G1	Q1	May-07	2.3	5
B3	Q4	Feb-08	2.3	5	G1	Q2	Aug-07	2.3	5
B4	Q1	May-07	2.3	5	G2	Q1	May-07	2.3	5
B4	Q1	May-07	5	5	G2	Q2	Aug-07	11.7	5
B4	Q2	Aug-07	2.3	5	G2	Q3	Dec-07	10.2	5
B4	Q3	Dec-07	2.3	5	G2	Q4	Feb-08	5	5
B4	Q4	Feb-08	2.3	5	G3	Q1	May-07	2.6	5
B5	Q4	Feb-08	2.3	5	G3	Q2	Aug-07	10.1	5

Station	Quarter	Date	(µg/L)		Station	Quarter	Date	(µg/L)	
			Total Cr	Cr (VI)				Total Cr	Cr (VI)
C1	Q1	May-07	2.3	5	G4	Q1	May-07	4.2	5
C1	Q2	Aug-07	2.3	5	G4	Q2	Aug-07	13.4	5
C1	Q3	Dec-07	2.3	5	G4	Q3	Dec-07	8.1	5
C1	Q4	Feb-08	2.3	5	G4	Q4	Feb-08	3.2	5
C2	Q1	May-07	2.3	5	H1	Q1	May-07	2.8	5
C2	Q2	Aug-07	2.3	5	H1	Q2	Aug-07	4.4	5
C2	Q3	Dec-07	2.3	5	H1	Q3	Dec-07	11	5
C2	Q4	Feb-08	2.4	5	H1	Q3-Dup	Dec-07	11	5
C3	Q1	May-07	2.3	5	H1	Q4	Feb-08	5.1	5
C3	Q2	Aug-07	2.3	5	H2	Q1	May-07	4.3	5
C3	Q3	Dec-07	3.4	5	H2	Q2	Aug-07	3.5	5
C3	Q4	Feb-08	2.3	5	H3	Q1	Dec-07	5.5	5
C4	Q1	May-07	2.3	5	H3	Q2	Feb-08	3.2	5
C4	Q2	Aug-07	2.3	5	H4	Q1	May-07	3.1	5
C4	Q2-Dup	Aug-07	2.3	5	H4	Q2	Aug-07	4.8	5
C4	Q3	Dec-07	3.8	5	H4	Q3	Dec-07	12.2	5
C4	Q4	Feb-08	2.3	5	H4	Q4	Feb-08	6.5	5
D1	Q1	May-07	3.3	5	H4	Q4-Dup	Feb-08	10.2	5
D1	Q2	Aug-07	11	5	I1	Q1	May-07	2.3	5
D1	Q3	Dec-07	11.7	5	I1	Q2	Aug-07	2.3	5
D1	Q4	Feb-08	4.3	5	I1	Q3	Dec-07	3.1	5
D1	Q4-Dup	Feb-08	2.3	5	I1	Q4	Feb-08	2.3	5
D2	Q1	May-07	3.3	5	I2	Q1	May-07	2.6	5
D2	Q2	Aug-07	16.2	5	I2	Q2	Aug-07	2.3	5
D2	Q3	Dec-07	9	5	I2	Q3	Dec-07	3.1	5
D2	Q4	Feb-08	4.4	5	I2	Q4	Feb-08	2.3	5
D3	Q1	May-07	8.5	5	I3	Q1	May-07	2.3	5
D3	Q2	Aug-07	12.4	5	I3	Q2	Aug-07	2.7	5
D3	Q3	Dec-07	6.6	5	I3	Q3	Dec-07	4.7	5
D3	Q4	Feb-08	3.7	5	I3	Q4	Feb-08	2.3	5
D4	Q1	May-07	2.3	5	I4	Q1	May-07	2.7	5
D4	Q2	Aug-07	3.1	5	I4	Q2	Aug-07	5.8	5
D4	Q3	Dec-07	2.3	5	I4	Q3	Dec-07	6.7	5
D4	Q3-Dup	Dec-07	2.3	5	I4	Q4	Feb-08	2.3	5
D4	Q4	Feb-08	2.3	5	J1	Q4	Feb-08	2.3	5
E1	Q1	May-07	4.8	5	J2	Q4	Feb-08	2.3	5

Station	Quarter	Date	Sediment Concentration (mg/kg)				
			Total Cr	Fe (II)	TOC	Mn (II)	Sulfides
A1	Q1	May-07	698	600	17,000	0.5	33.2
A1	Q2	Aug-07	1,200	5,140	480	2.237	328
A1	Q2	Aug-07	1,330	4,130	4,900	1.464	603
A1	Q2	Aug-07	17	85.8	260	1.478	23.4
A2	Q1	May-07	363	85.1	390	0.5	25.6
A2	Q2	Aug-07	347	500	270	2.181	45.3
A2	Q2	Aug-07	315	-	-	-	-
A2	Q2	Aug-07	78.3	-	-	-	-
A3	Q1	May-07	96.6	334	710	0.5	41.3
A3	Q2	Aug-07	110	250	270	2.144	200
A3	Q2	Aug-07	2.91	-	-	-	-
A3	Q2	Aug-07	3.94	-	-	-	-
A4	Q1	May-07	89.6	103	200	0.5	25.7
A4	Q2	Aug-07	97.4	129	260	2.194	386
A4	Q2	Aug-07	12.8	-	-	-	-
A4	Q2	Aug-07	34.1	-	-	-	-
B1	Q1	May-07	640	NA	15,000	0.5	33.8
B1	Q2	Aug-07	595	4,280	11,000	2.252	77.3
B1	Q2	Aug-07	80.9	1,990	6,800	1.612	67.3
B1	Q2	Aug-07	29.4	655	490	4.793	24.9
B2	Q1	May-07	369	802	12,000	0.5	401
B2	Q2	Aug-07	236	2,220	6,600	2.224	92
B2	Q2	Aug-07	22.7	-	-	-	-
B2	Q2	Aug-07	1.97	-	-	-	-
B3	Q1	May-07	683	731	18,000	2.55	65
B3	Q2	Aug-07	637	2,030	24,000	2.211	1,420
B3	Q2	Aug-07	94	-	-	-	-
B3	Q2	Aug-07	1.15	-	-	-	-
B4	Q1	May-07	424	29.2	14,000	0.5	142
B4	Q1-Dup	May-07	355	657	10000	0.823	145
B4	Q2	Aug-07	404	1,850	11,000	2.345	528
B4	Q2	Aug-07	2,290	-	-	-	-
B4	Q2	Aug-07	690	-	-	-	-
B5	Q4	Feb-08	54.3	410	838	-	-
B5	Q4-Dup	Feb-08	58.2	238	614	-	-

			Total Cr	Fe (II)	TOC	Mn (II)	Sulfides
B5	Q4	Feb-08	43.6	589	672	-	-
B5	Q4	Feb-08	37.9	221	670	-	-
C1	Q1	May-07	1,160	5,840	17,000	0.5	1,090
C1	Q2	Aug-07	1,310	10,600	25,000	2.298	1,780
C1	Q2	Aug-07	2,090	24,400	24,000	1.544	1,300
C1	Q2	Aug-07	-	21300	-	-	-
C1	Q2	Aug-07	1440	21,300	9,800	1.485	1,910
C1	Q2-Dup	Aug-07	1,800	-	2500	-	-
C2	Q1	May-07	1,080	4,670	25,000	0.5	73.5
C2	Q2	Aug-07	1,070	5,570	20,000	2.267	509
C2	Q2	Aug-07	91.5	-	-	-	-
C2	Q2	Aug-07	3.62	-	-	-	-
C3	Q1	May-07	582	3,430	9,500	0.5	96.4
C3	Q2	Aug-07	618	6,470	18,000	2.272	313
C3	Q2	Aug-07	250	-	-	-	-
C3	Q2	Aug-07	78.3	-	-	-	-
C4	Q1	May-07	357	3,150	9,700	0.5	33.8
C4	Q2	Aug-07	315	6,500	14,000	2.346	54.4
C4	Q2-Dup	Aug-07	328	6370	14,000	2.313	158
C4	Q2	Aug-07	57	-	-	-	-
C4	Q2	Aug-07	2.32	-	-	-	-
D1	Q1	May-07	304	9,770	25,000	5.924	1,880
D1	Q2	Aug-07	310	14,400	29,000	19.578	2,040
D1	Q2	Aug-07	372	16,400	51,000	10.285	2,330
D1	Q2	Aug-07	251	10,500	32,000	2.496	418
D2	Q1	May-07	239	13,000	29,000	7.75	2,020
D2	Q2	Aug-07	258	8,830	34,000	10.47	2,760
D2	Q2	Aug-07	237	-	-	-	-
D2	Q2	Aug-07	66.1	-	-	-	-
D3	Q1	May-07	306	1,290	25,000	2.678	476
D3	Q2	Aug-07	253	5,870	28,000	34.002	2,090
D3	Q2	Aug-07	218	-	-	-	-
D3	Q2	Aug-07	95.8	-	-	-	-
D4	Q1	May-07	198	5,120	13,000	0.5	36.5
D4	Q2	Aug-07	214	3,060	15,000	2.318	261
D4	Q2	Aug-07	78.1	-	-	-	-
D4	Q2	Aug-07	60.2	-	-	-	-

E1	Q1	May-07	223	83	30,000	2.785	658
E1	Q1-Dup	May-07	200	41	20,000	0.5	305
E1	Q2	Aug-07	253	10,700	23,000	2.449	1,680
E1	Q2	Aug-07	217	11,200	41,000	2.494	1,210
E1	Q2	Aug-07	68.2	4,700	30,000	2.244	125
E2	Q1	May-07	67	5,320	19,000	4.848	708
E2	Q2	Aug-07	65	5,910	25,000	7.304	1,900
E2	Q2	Aug-07	61	-	-	-	-
E2	Q2	Aug-07	62.1	-	-	-	-
E3	Q1	May-07	238	13,600	18,000	8.539	1,320
E3	Q2	Aug-07	197	11,200	21,000	10.258	2,120
E3	Q2	Aug-07	262	-	-	-	-
E3	Q2	Aug-07	259	-	-	-	-
E4	Q1	May-07	61.2	1,010	7,300	0.5	28.5
E4	Q2	Aug-07	114	1,150	16,000	2.18	361
E4	Q2	Aug-07	52.1	-	-	-	-
E4	Q2	Aug-07	125	-	-	-	-
F1	Q1	May-07	97.9	5,810	15,000	3.225	570
F1	Q2	Aug-07	117	4,840	20,000	2.372	1,160
F1	Q2	Aug-07	76.7	8,810	15,000	2.807	1,050
F1	Q2	Aug-07	159	15,200	30,000	1.651	2,380
F2	Q1	May-07	65.8	3,640	20,000	1.483	38
F2	Q2	Aug-07	33.1	808	3,000	2.219	224
F2	Q2	Aug-07	49.3	-	-	-	-
F2	Q2	Aug-07	36.9	-	-	-	-
F3	Q1	May-07	152	13,400	25,000	0.5	1,720
F3	Q2	Aug-07	211	8890	24000	2.418	1050
F3	Q2-Dup	Aug-07	261	11,500	25,000	4.005	2,350
F3	Q2	Aug-07	56	-	-	-	-
F3	Q2	Aug-07	56.2	-	-	-	-
F4	Q1	May-07	211	7,580	26,000	0.778	555
F4	Q2	Aug-07	190	11,300	20,000	2.431	2,000
F4	Q2	Aug-07	120	-	-	-	-
F4	Q2-Dup	Aug-07	159	-	-	-	-
F4	Q2	Aug-07	55.1	-	-	-	-
F4	Q2-Dup	Aug-07	54	-	-	-	-
G1	Q1	May-07	67	1,250	5,900	1	152

			Total Cl	Fe (II)	TOC	Mn (II)	Sulfides
G1	Q2	Aug-07	67	4,340	7,200	1.521	1,170
G1	Q2	Aug-07	33	3,700	22,000	1.526	102
G1	Q2	Aug-07	28.8	5,170	9,700	1.505	128
G2	Q1	May-07	123	6,210	14,000	2	896
G2	Q2	Aug-07	153	6,410	28,000	2.458	1,500
G2	Q2	Aug-07	144	-	-	-	-
G2	Q2	Aug-07	50	-	-	-	-
G3	Q1	May-07	148	28	17,000	4.083	449
G3	Q2	Aug-07	164	8,510	13,000	2.421	1,900
G3	Q2	Aug-07	29.8	-	-	-	-
G3	Q2	Aug-07	29.6	-	-	-	-
G4	Q1	May-07	121	15	17,000	13.992	1,430
G4	Q2	Aug-07	140	4,170	9,100	2.371	1,650
G4	Q2	Aug-07	182	-	-	-	-
G4	Q2	Aug-07	197	-	-	-	-
H1	Q1	May-07	114	11,100	25,000	10.439	2,630
H1	Q2	Aug-07	89.5	7,410	21,000	2.404	2,690
H1	Q2	Aug-07	182	9,980	35,000	2.342	2,400
H1	Q2	Aug-07	29.2	493	860	1.441	35.1
H2	Q1	May-07	47.1	1,900	8,700	1	203
H2	Q2	Aug-07	134	2,180	29,000	2.403	1,040
H2	Q2	Aug-07	43.2	-	-	-	-
H2	Q2	Aug-07	88.4	-	-	-	-
H3	Q1	May-07	49.3	8,330	12,000	1	1,480
H3	Q2	Aug-07	71.8	6,100	9,800	9.836	1,870
H3	Q2	Aug-07	71.7	-	-	-	-
H3	Q2	Aug-07	101	-	-	-	-
H4	Q1	May-07	107	12,800	20,000	3.842	732
H4	Q2	Aug-07	207	13,200	48,000	13.377	3,470
H4	Q2	Aug-07	80.7	-	-	-	-
H4	Q2	Aug-07	28	-	-	-	-
I1	Q1	May-07	316	6,600	20,000	1	311
I1	Q2	Aug-07	700	4,490	14,000	2	1,240
I1	Q2	Aug-07	17	5,270	3,100	1.453	815
I1	Q2	Aug-07	22	6,100	11,000	1.498	1,060
I2	Q1	May-07	254	2,410	40,000	1	292
I2	Q2	Aug-07	315	5,580	34,000	2	1,600

I2	Q2	Aug-07	308	-	-	-	-
I2	Q2	Aug-07	575	-	-	-	-
I3	Q1	May-07	357	3,630	36,000	0.582	1,140
I3	Q2	Aug-07	425	5,960	39,000	5.431	2,070
I3	Q2	Aug-07	327	-	-	-	-
I3	Q2	Aug-07	332	-	-	-	-
I4	Q1	May-07	374	8,210	33,000	0.5	1,000
I4	Q2	Aug-07	542	4,570	39,000	1.836	1,690
I4	Q2	Aug-07	1,390	-	-	-	-
I4	Q2	Aug-07	508	-	-	-	-
J1	Q4	Feb-08	1,830	2,690	21,500	-	-
J1	Q4	Feb-08	1,620	6,340	10,900	-	-
J1	Q4	Feb-08	2,730	11,900	18,000	-	-
J2	Q4	Feb-08	1,840	2,050	9,640	-	-
J2	Q4	Feb-08	605	1,060	10,900	-	-
J2	Q4	Feb-08	303	701	679	-	-
J3	Q4	Feb-08	1,260	4,910	13,600	-	-
J3	Q4	Feb-08	28.2	144	769	-	-
J3	Q4	Feb-08	567	176	9,590	-	-
J4	Q4	Feb-08	2,360	818	9,670	-	-
J4	Q4	Feb-08	8,140	1,550	762	-	-
J4	Q4	Feb-08	114	22	572	-	-

Station	Date	AVS/SEM Concentration (µmole/g)										
		AVS	Cd	Cu	Pb	Ni	Hg	Zn	Fe	Total Metals	Excess AVS	Excess Fe
A1	May-07	0.44	0.0045	0.27	0.09	0.59	2.80E-05	1.86	92.80	2.81	-2.37	92.36
A1	Aug-07	12.10	0.0019	0.06	0.09	0.18	-	1.79	71.90	2.12	9.98	59.80
A1	Aug-07	-	-	-	-	-	-	-	-	-	-	-
A1	Aug-07	-	-	-	-	-	-	-	-	-	-	-
A2	May-07	0.39	0.0007	0.05	0.03	0.11	2.60E-05	0.47	20.00	0.66	-0.27	19.61
A2	Aug-07	0.57	0.0001	0.06	0.04	0.13	-	0.55	25.40	0.77	-0.20	24.83
A2	Aug-07	-	-	-	-	-	-	-	-	-	-	-
A2	Aug-07	-	-	-	-	-	-	-	-	-	-	-
A3	May-07	0.52	0.0005	0.04	0.02	0.03	7.70E-06	0.29	17.50	0.37	0.15	16.98
A3	Aug-07	0.99	0.0001	0.12	0.02	0.63	-	0.22	20.10	0.99	0.00	19.11
A3	Aug-07	-	-	-	-	-	-	-	-	-	-	-
A3	Aug-07	-	-	-	-	-	-	-	-	-	-	-
A4	May-07	0.39	0.0007	0.05	0.02	0.11	7.60E-06	0.31	29.20	0.49	-0.10	28.81
A4	Aug-07	1.40	0.0001	0.03	0.02	0.02	-	0.28	17.20	0.36	1.04	15.80
A4	Aug-07	-	-	-	-	-	-	-	-	-	-	-
A4	Aug-07	-	-	-	-	-	-	-	-	-	-	-
B1	May-07	0.44	0.0016	0.30	0.08	0.57	1.40E-05	1.40	82.00	2.35	-1.91	81.56
B1	Aug-07	10.40	0.0027	0.11	0.07	0.48	-	1.22	73.70	1.88	8.52	63.30
B1	Aug-07	-	-	-	-	-	-	-	-	-	-	-
B1	Aug-07	-	-	-	-	-	-	-	-	-	-	-
B2	May-07	0.53	0.0015	0.28	0.06	0.50	2.90E-05	0.97	74.40	1.82	-1.29	73.87
B2	Aug-07	3.20	0.0016	0.16	0.06	0.06	-	0.91	52.10	1.19	2.01	48.90
B2	Aug-07	-	-	-	-	-	-	-	-	-	-	-
B2	Aug-07	-	-	-	-	-	-	-	-	-	-	-
B3	May-07	7.70	0.0037	0.16	0.12	0.43	7.70E-06	1.47	102.00	2.18	5.52	94.30
B3	Aug-07	11.60	0.0039	0.34	0.13	0.69	-	1.62	107.00	2.78	8.82	95.40
B3	Aug-07	-	-	-	-	-	-	-	-	-	-	-
B3	Aug-07	-	-	-	-	-	-	-	-	-	-	-
B4	May-07	3.40	0.0006	0.40	0.14	0.09	7.50E-06	1.70	125.00	2.32	1.08	121.60
B4	May-07	4.30	0.0004	0.40	0.12	0.40	7.80E-06	1.54	122.00	2.46	1.84	117.70
B4	Aug-07	3.80	0.0046	0.46	0.15	0.40	-	1.93	121.00	2.94	0.86	117.20
B4	Aug-07	-	-	-	-	-	-	-	-	-	-	-
B4	Aug-07	-	-	-	-	-	-	-	-	-	-	-
B5	Feb-08	0.63	0.0009	0.10	0.03	0.04	-	0.51	39.40	0.68	-0.05	38.77
B5	Feb-08	0.74	0.0008	0.09	0.03	0.04	-	0.48	35.70	0.64	0.10	34.96

		AVS	Cd	Cu	Pb	Ni	Ag	Zn	ΣSEM	Metals	AVS	Fe
B5	Feb-08	0.63	0.0004	0.07	0.02	0.04	-	0.21	45.20	0.35	0.28	44.57
B5	Feb-08	0.63	0.0001	0.02	0.00	0.03	-	0.03	25.30	0.08	0.55	24.67
C1	May-07	12.60	0.0017	0.14	0.13	0.37	7.50E-06	1.60	136.00	2.25	10.35	123.40
C1	Aug-07	14.30	0.0057	0.22	0.18	0.68	-	1.85	109.00	2.93	11.37	94.70
C1	Aug-07	-	-	-	-	-	-	-	-	-	-	-
C1	Aug-07	-	-	-	-	-	-	-	-	-	-	-
C1	Aug-07	-	-	-	-	-	-	-	-	-	-	-
C1	Aug-07	-	-	-	-	-	-	-	-	-	-	-
C2	May-07	13.10	0.0053	0.14	0.17	0.25	7.80E-06	1.74	92.60	2.30	10.80	79.50
C2	Aug-07	16.00	0.0043	0.15	0.17	0.21	-	1.68	98.60	2.21	13.79	82.60
C2	Aug-07	-	-	-	-	-	-	-	-	-	-	-
C2	Aug-07	-	-	-	-	-	-	-	-	-	-	-
C3	May-07	9.80	0.0048	0.19	0.13	0.43	7.70E-06	1.88	101.00	2.62	7.18	91.20
C3	Aug-07	6.50	0.0047	0.29	0.12	0.11	-	1.96	84.00	2.49	4.01	77.50
C3	Aug-07	-	-	-	-	-	-	-	-	-	-	-
C3	Aug-07	-	-	-	-	-	-	-	-	-	-	-
C4	May-07	4.90	0.0051	0.40	0.13	0.18	7.50E-06	1.86	125.00	2.58	2.32	120.10
C4	Aug-07	3.30	0.0044	0.35	0.13	0.28	-	1.81	107.00	2.57	0.73	103.70
C4	Aug-07	7.10	0.0044	0.36	0.13	0.08	-	1.84	92.00	2.42	4.68	84.90
C4	Aug-07	-	-	-	-	-	-	-	-	-	-	-
C4	Aug-07	-	-	-	-	-	-	-	-	-	-	-
D1	May-07	28.80	0.0010	0.05	0.09	0.16	7.50E-06	1.17	103.00	1.46	27.34	74.20
D1	Aug-07	18.70	0.0024	0.13	0.08	0.16	-	1.02	74.70	1.39	17.31	56.00
D1	Aug-07	-	-	-	-	-	-	-	-	-	-	-
D1	Aug-07	-	-	-	-	-	-	-	-	-	-	-
D2	May-07	16.60	0.0010	0.20	0.09	0.06	7.60E-06	1.04	82.50	1.38	15.22	65.90
D2	Aug-07	32.70	0.0027	0.03	0.08	0.09	-	0.99	87.90	1.19	31.51	55.20
D2	Aug-07	-	-	-	-	-	-	-	-	-	-	-
D2	Aug-07	-	-	-	-	-	-	-	-	-	-	-
D3	May-07	15.30	0.0010	0.13	0.09	0.12	7.60E-06	0.99	80.40	1.32	13.98	65.10
D3	Aug-07	11.40	0.0032	0.15	0.10	0.36	-	1.20	86.70	1.82	9.58	75.30
D3	Aug-07	-	-	-	-	-	-	-	-	-	-	-
D3	Aug-07	-	-	-	-	-	-	-	-	-	-	-
D4	May-07	13.20	0.0018	0.25	0.09	0.37	7.60E-06	1.10	170.00	1.82	11.38	156.80
D4	Aug-07	10.30	0.0041	0.38	0.15	0.59	-	1.74	162.00	2.86	7.44	151.70
D4	Aug-07	-	-	-	-	-	-	-	-	-	-	-
D4	Aug-07	-	-	-	-	-	-	-	-	-	-	-
E1	May-07	22.90	0.0008	0.0604*	0.08	0.06	7.80E-06	0.89	75.10	1.03	21.87	52.20
[illegible]	[illegible]-07	13.10	0.0008	0.10	0.04	0.13	7.60E-06	0.80	47.90	1.08	11.02	35.80

Station	Date	AVS	Cd	Cu	Pb	Ni	Hg	Zn	Fe	Total Metals	Excess AVS	Excess Fe
E1	Aug-07	19.00	0.0025	0.05	0.07	0.06	-	0.95	68.50	1.13	17.87	49.50
E1	Aug-07	-	-	-	-	-	-	-	-	-	-	-
E1	Aug-07	-	-	-	-	-	-	-	-	-	-	-
E2	May-07	6.80	0.0020	0.14	0.04	0.25	7.60E-06	0.56	139.00	0.99	5.81	132.20
E2	Aug-07	20.10	0.0039	0.09	0.06	0.56	-	0.68	77.60	1.40	18.70	57.50
E2	Aug-07	-	-	-	-	-	-	-	-	-	-	-
E2	Aug-07	-	-	-	-	-	-	-	-	-	-	-
E3	May-07	27.50	0.0035	0.20	0.08	0.43	7.60E-06	1.08	105.00	1.79	25.71	77.50
E3	Aug-07	25.10	0.0029	0.05	0.09	0.34	-	1.03	97.40	1.50	23.60	72.30
E3	Aug-07	-	-	-	-	-	-	-	-	-	-	-
E3	Aug-07	-	-	-	-	-	-	-	-	-	-	-
E4	May-07	0.93	0.0011	0.18	0.09	0.04	9.90E-06	0.49	60.40	0.79	0.14	59.47
E4	Aug-07	7.60	0.0018	0.21	0.09	0.28	-	0.72	61.00	1.29	6.31	53.40
E4	Aug-07	-	-	-	-	-	-	-	-	-	-	-
E4	Aug-07	-	-	-	-	-	-	-	-	-	-	-
F1	May-07	12.90	0.0005	0.13	0.05	0.05	7.80E-06	0.64	69.40	0.87	12.03	56.50
F1	Aug-07	19.90	0.0025	0.19	0.07	1.00	-	0.92	91.60	2.18	17.72	71.70
F1	Aug-07	-	-	-	-	-	-	-	-	-	-	-
F1	Aug-07	-	-	-	-	-	-	-	-	-	-	-
F2	May-07	9.50	0.0005	0.17	0.05	0.05	7.80E-06	0.62	80.60	0.89	8.61	71.10
F2	Aug-07	4.20	0.0008	0.15	0.03	0.50	-	0.16	109.00	0.84	3.36	104.80
F2	Aug-07	-	-	-	-	-	-	-	-	-	-	-
F2	Aug-07	-	-	-	-	-	-	-	-	-	-	-
F3	May-07	22.00	0.0038	0.29	0.15	0.07	7.60E-06	1.33	172.00	1.84	20.16	150.00
F3	Aug-07	41.50	0.0037	0.17	0.11	0.08	-	1.13	110.00	1.49	40.01	68.50
F3	Aug-07	21.50	0.0028	0.11	0.08	0.16	-	0.85	94.20	1.20	20.30	72.70
F3	Aug-07	-	-	-	-	-	-	-	-	-	-	-
F3	Aug-07	-	-	-	-	-	-	-	-	-	-	-
F4	May-07	20.60	0.0029	0.27	0.10	0.12	7.60E-06	1.15	107.00	1.64	18.96	86.40
F4	Aug-07	8.40	0.0026	0.06	0.08	0.04	-	0.90	75.10	1.08	7.32	66.70
F4	Aug-07	-	-	-	-	-	-	-	-	-	-	-
F4	Aug-07	-	-	-	-	-	-	-	-	-	-	-
F4	Aug-07	-	-	-	-	-	-	-	-	-	-	-
F4	Aug-07	-	-	-	-	-	-	-	-	-	-	-
G1	May-07	6.80	0.0001	0.07	0.02	0.17	7.60E-06	0.26	48.70	0.52	6.28	41.90
G1	Aug-07	21.20	0.0024	0.10	0.05	0.65	-	0.57	68.70	1.38	19.82	47.50
G1	Aug-07	-	-	-	-	-	-	-	-	-	-	-
G1	Aug-07	-	-	-	-	-	-	-	-	-	-	-

										Metals	AVS	Fe
G2	Aug-07	17.10	0.0029	0.20	0.07	0.16	-	0.86	68.40	1.29	15.81	51.30
G2	Aug-07	-	-	-	-	-	-	-	-	-	-	-
G2	Aug-07	-	-	-	-	-	-	-	-	-	-	-
G3	May-07	23.90	0.0016	0.14	0.08	0.29	7.80E-06	0.85	74.30	1.35	22.55	50.40
G3	Aug-07	25.60	0.0036	0.15	0.08	0.44	-	0.97	81.90	1.65	23.95	56.30
G3	Aug-07	-	-	-	-	-	-	-	-	-	-	-
G3	Aug-07	-	-	-	-	-	-	-	-	-	-	-
G4	May-07	22.20	0.0015	0.13	0.09	0.29	7.80E-06	1.02	100.00	1.53	20.67	77.80
G4	Aug-07	10.20	0.0030	0.09	0.08	0.06	-	0.91	72.20	1.13	9.07	62.00
G4	Aug-07	-	-	-	-	-	-	-	-	-	-	-
G4	Aug-07	-	-	-	-	-	-	-	-	-	-	-
H1	May-07	51.20	0.0363	0.43	0.18	0.50	7.80E-06	1.86	71.00	3.01	48.19	19.80
H1	Aug-07	16.90	0.0070	0.01	0.07	0.04	-	0.80	61.00	0.94	15.96	44.10
H1	Aug-07	-	-	-	-	-	-	-	-	-	-	-
H1	Aug-07	-	-	-	-	-	-	-	-	-	-	-
H2	May-07	20.80	0.0149	0.23	0.10	0.04	7.70E-06	0.98	48.70	1.36	19.44	27.90
H2	Aug-07	32.20	0.0109	0.02	0.10	0.27	-	0.95	57.90	1.34	30.86	25.70
H2	Aug-07	-	-	-	-	-	-	-	-	-	-	-
H2	Aug-07	-	-	-	-	-	-	-	-	-	-	-
H3	May-07	36.50	0.0095	0.14	0.09	0.05	7.60E-06	0.95	60.70	1.25	35.25	24.20
H3	Aug-07	16.40	0.0114	0.02	0.08	0.31	-	0.72	36.20	1.14	15.26	19.80
H3	Aug-07	-	-	-	-	-	-	-	-	-	-	-
H3	Aug-07	-	-	-	-	-	-	-	-	-	-	-
H4	May-07	24.50	0.0044	0.23	0.07	0.34	7.50E-06	0.82	82.60	1.46	23.04	58.10
H4	Aug-07	38.30	0.0294	0.09	0.15	0.25	-	1.49	58.90	2.01	36.29	20.60
H4	Aug-07	-	-	-	-	-	-	-	-	-	-	-
H4	Aug-07	-	-	-	-	-	-	-	-	-	-	-
I1	May-07	3.20	0.1420	1.02	0.39	0.31	7.60E-06	4.69	63.40	6.55	-3.35	60.20
I1	Aug-07	26.50	0.0746	0.00	0.23	0.48	-	3.19	78.10	3.97	22.53	51.60
I1	Aug-07	-	-	-	-	-	-	-	-	-	-	-
I1	Aug-07	-	-	-	-	-	-	-	-	-	-	-
I2	May-07	10.60	0.0880	0.53	0.35	0.63	7.70E-06	3.14	59.90	4.74	5.86	49.30
I2	Aug-07	23.80	0.0856	0.01	0.23	0.74	-	3.01	57.80	4.08	19.72	34.00
I2	Aug-07	-	-	-	-	-	-	-	-	-	-	-
I2	Aug-07	-	-	-	-	-	-	-	-	-	-	-
I3	May-07	24.40	0.1210	0.12	0.54	0.55	7.50E-06	3.60	55.50	4.93	19.47	31.10
I3	Aug-07	21.50	0.1690	0.00	0.49	0.04	-	5.56	32.70	6.26	15.24	11.20
I3	Aug-07	-	-	-	-	-	-	-	-	-	-	-
I3	Aug-07	-	-	-	-	-	-	-	-	-	-	-

		AVS	Cd	Cu	Pb	Ni	Hg	Zn	Fe	Metals	AVS	Fe
I4	May-07	42.70	0.1920	0.09	0.63	0.54	7.70E-06	4.99	74.40	6.44	36.26	31.70
I4	Aug-07	11.90	0.0759	0.00	0.32	0.29	-	3.16	40.80	3.86	8.04	28.90
I4	Aug-07	-	-	-	-	-	-	-	-	-	-	-
I4	Aug-07	-	-	-	-	-	-	-	-	-	-	-
J1	Feb-08	5.00	0.0091	0.30	0.21	0.30	-	2.53	162.00	3.34	1.66	157.00
J1	Feb-08	7.10	0.0085	0.66	0.56	0.31	-	1.60	104.00	3.13	3.97	96.90
J1	Feb-08	10.00	0.0048	0.23	0.12	0.18	-	1.39	79.80	1.92	8.08	69.80
J2	Feb-08	16.80	0.0057	0.15	0.06	0.41	-	1.20	127.00	1.84	14.96	110.20
J2	Feb-08	4.80	0.0055	0.35	0.13	0.16	-	2.29	104.00	2.93	1.87	99.20
J2	Feb-08	5.00	0.0115	0.24	0.19	0.18	-	3.12	45.80	3.73	1.27	40.80
J3	Feb-08	0.63	0.0014	0.15	0.05	0.22	-	0.95	89.40	1.37	-0.74	88.77
J3	Feb-08	6.60	0.0026	0.19	0.07	0.08	-	1.16	63.80	1.51	5.09	57.20
J3	Feb-08	0.63	0.0001	0.03	0.00	0.00	-	0.01	12.10	0.05	0.58	11.47
J4	Feb-08	2.40	0.0072	0.19	0.08	0.35	-	2.57	121.00	3.19	-0.79	118.60
J4	Feb-08	0.63	0.0019	0.26	0.15	0.69	-	4.24	192.00	5.34	-4.71	191.37
J4	Feb-08	0.63	0.0001	0.01	0.00	0.00	-	0.01	1.11	0.02	0.61	0.48

Regarding the Water Quality Analysis of Chromium in Northwest Branch and Bear Creek Portions of the Patapsco River Mesohaline Tidal Chesapeake Bay Segment, Baltimore City and Baltimore County, Maryland

The Maryland Department of the Environment (MDE) has conducted a public review of the proposed Water Quality Analysis (WQA) of Chromium in the Northwest Branch and Bear Creek Portions of the Patapsco River Mesohaline Tidal Chesapeake Bay Segment. The public comment period was open from April 16, 2013 through May 15, 2013. MDE received three sets of written comments.

Below is a list of commentors, their affiliation, the date comments were submitted, and the number referenced to the comments submitted. In the pages that follow, comments are summarized and listed with MDE's response.

Author	Affiliation	Date	Comment Number
Mr. Steve Stewart, Mr. Kevin Brittingham and Ms. Erin Wisnieski	**Baltimore County Dept. of Environmental Protection & Sustainability**	**5/9/2013**	**1 – 6**
Ms. Mary Sorensen	**ENVIRON, consultants for Maryland Port Admin. & Honeywell International, Inc.**	**5/14/2013**	**7 - 11**
Ms. Tina Meyers	**Baltimore Harbor WATERKEEPER/Blue Water Baltimore**	**5/15/2013**	**12 - 16**

Comments and Responses

1. The commentor states that there are two mentions of the Trash TMDL [in the Baltimore Harbor Chromium WQA] (Exec. Summary and Intro). The commentor asks if MDE still plans to submit [the Trash TMDL] to EPA in 2013?

   Response: The language in the Executive Summary and Introduction regarding the status of the trash listing has now been revised to state that the Trash TMDL will be addressed at a future date. The TMDL submittal to EPA has been delayed in order to complete a full re-evaluation of the TMDL and its methodology. EPA has been notified of and is in agreement with this decision. This re-evaluation is anticipated to produce a more robust TMDL document.

   MDE is fully committed to addressing all of the impairment listings in the Patapsco River Mesohaline Tidal Chesapeake Bay Segment (PATMH), including the trash impairment. MDE is cognizant of the comments it has received expressing concerns regarding the serious and detrimental nature of trash to recreation and

In addition to the TMDL development, the trash impairment is also being addressed through the municipal separate storm sewer system (MS4) permits for Baltimore City and Baltimore County. Both of these permits are in the process of being renewed and will contain specific language regarding requirements to reduce the trash impairment, including: inventory of and improvements to current trash reduction practices, development and evaluation of an educational/outreach program, and annual reporting of trash reduction strategies.

The Department will keep the commentor informed of any progress regarding this project, via mail, email or our website. Once the re-evaluation is complete, if the TMDL has been significantly changed, a full public comment period will be conducted.

2. The commentor states that on page 19 [of the WQA], there was a mention of 3210 mg/kg Cr as highest spiking level in the text, but in Table 5.1.1(a) there is a 4180 mg/kg Cr spike as well.

   Response: The first paragraph on page 19 states that the highest spiking level of 3,210 mg/kg is specifically for station BSM 68. The column labeled Spike C in Table 5.1.1(a) displays the highest spiking level for each sediment sample. The maximum spiking level for all sediment samples (4,180 mg/kg) applies to station BSM 45.

3. The commentor states that at the end of the 2nd Paragraph on page 31 [of the WQA] the mention of fresh sediment burying "historically contaminated sediments" brings to mind a few questions: How are the sediment samples taken and/or how deep into the sediment?

   Response: Sediment samples are collected from the top 2 cm of bottom sediments using a sediment ponar grab sampler. These samples are representative of the active layer in which benthic organisms live and feed.

4. The commentor asks if sediments at different depths have different Cr levels.

   Response: Concentrations of chromium within the sediments of the Baltimore Harbor will most likely be higher with increasing depth due to greater historical releases of chromium from past industrial activities (*e.g.* chromium extraction and steel manufacturing processes). The highest levels of chromium deposition would most likely have occurred in the past when these industries were operating at peak levels. This WQA establishes that chromium is not a source of toxicity within the inhabitable zone of the sediment, the active layer from which sediment samples

sediment core is not necessary for assessing sediment quality.

5. The commentor asks what the consequences of dredging, storm activity, etc. may be.

   Response: The dissertation "Geochemical Influences on Chromium Speciation and Fate in Estuarine Sediments; Importance of Redox Interactions with Manganese Sulfide Minerals" referenced in section 5.1.3 on page 23 of the WQA investigated chromium speciation and fate in Baltimore Harbor sediments under oxygenation to replicate conditions of sediment resuspension that may occur due to dredging, bioturbation, and flood events. This study was completed by Amar Wadhawan of the Johns Hopkins University Center for Contaminant Transport, Fate and Remediation (JHU CTFR), under the direction of Dr. Edward Bouwer, professor and department chair of Geography and Environmental Engineering. In this study, field sediments collected from various locations throughout the Baltimore Harbor, including the Bear Creek and Northwest Branch tidal segments addressed in this WQA, were suspended and re-oxygenated for extended periods of time, upwards of thirty days, resulting in no oxidation of Cr (III) to Cr (VI). Therefore, under conditions of resuspension due to dredging or storm activity, there will be no consequences as chromium in sediments of the Baltimore Harbor will remain as Cr (III), resulting in no toxicological impact to the benthic community. Please refer to section 5.1.3 for additional information.

6. The commentor asks if synergistic effects were included. If not, it should be included in future investigations.

   Response: Synergistic effects are not directly investigated within this WQA, however, they are implicitly accounted for in establishing that chromium is not a source of toxicity within the sediments of the Northwest Branch and Bear Creek. In order to assess synergistic effects directly it would require conducting laboratory sediment bioassays for an endless array of substances at varying concentrations to determine a conservative threshold at which a specific contaminant is toxic to aquatic life. EPA's nationally recommended water quality criteria are developed for individual contaminants and do not incorporate synergistic effects except for the adjustment of heavy metals criteria based on the mitigating effects of hardness.

   While synergy is not directly investigated, this WQA does establish that chromium is not a source of toxicity in sediments in the presence of elevated levels of other toxic contaminants, indicating that synergistic effects do not induce chromium toxicity. Chromium is predominantly found in its trivalent state [Cr (III)], the relatively non-toxic species under the environmental conditions in this watershed. Reductants present within the system facilitate the conversion of Cr (VI) to Cr (III). Cr (III) will remain stable and relatively inert within these sediments where it will be biologically unavailable to benthic organisms. As Cr (III) is a non-toxic substance and does not adversely impact the health of aquatic organisms, there is no potential for toxic contaminants present within the system to enhance toxicity

would not require an assessment of synergy related to the toxicity of chromium.

7. The commentor states that while the UMD study [referenced in the WQA] was inconclusive on the compounds causing toxicity, the UMD provided a substantial amount of information showing that chromium was not the cause of toxicity. In order to emphasize this point, the commentor states that Section 5.0 would be improved with the addition of the following information at the conclusion of Section 5.1.1 (page 22):

"While the TIE was inconclusive in regard to implicating a particular metal or group of metals for the toxicity observed in Bear Creek / Northwest Branch, UMD provided a substantial amount of information showing that chromium was not the cause of toxicity via partition to porewater or via bulk sediment exposure."

Response: MDE appreciates the recommendations Environ has provided for further justification within this WQA establishing that chromium is not an impairing substance in the Northwest Branch and Bear Creek. After review of the recommendations, MDE has incorporated changes to the document in section 4.2.

8. The commentor states that while the WQA does a good job summarizing the Johns Hopkins University studies overall, there is one element of the Wadhawan (2012) dissertation that merits further amplification because of its importance to the story of potential Cr (VI) oxidation. In Section 5.1.3, the commentor recommends that the two paragraphs beginning on Page 25 (Paragraph 2) and continuing on to Page 27 (Paragraph 1) in the MDE 2013 WQA be replaced with the following three paragraphs (note that Page 26 contains figures only which would be retained as they are called out here or earlier):

"Wadhawan (2012) performed multiple experiments to evaluate the potential for chromium to oxidize from Cr(III) to Cr(VI). One experiment evaluated the potential for Cr(III) oxidation under anaerobic conditions, which is the predominant state of in-situ sediments. Cr(III) was added to Baltimore Harbor sediments that were maintained in an anaerobic condition. Addition of Cr(III) to anaerobic sediments resulted in no formation of Cr(VI) in any of the samples from multiple batch experiments (Wadhawan, Page 79, Paragraph 1 and page 87 Paragraph 1). A second experiment evaluated the potential for Cr(III) to oxidize to Cr(VI) under aerobic conditions, in which the sediment suspension was actively oxygenated using two approaches: (1) without the addition of Cr(III) and (2) with the addition of a laboratory grade, freshly prepared Cr(III) aqueous solution. With regard to approach (1), Wadhawan states that "Oxidation of background Cr(III) in sediments was insignificant as experimental controls of unspiked sediment suspensions did not show Cr(VI) formation upon aeration (data not shown)"(Wadhawan 2012, Page 87). The data that is not shown is that approach 1 involved the aeration of each of the Harbor sediment samples for up to 30 days, or 720 hours, as noted by Wadwahan (2012, Page 118). The experimental aeration period is very conservative in terms of reflecting the natural conditions of

these Harbor sediment - 3 - samples indicate that Cr(VI) formation due to sediment suspension will not occur under normal conditions in Baltimore Harbor.
The oxidation of Cr(III) to Cr(VI) was further evaluated by Wadhawan (2012) using approach (2) through the spiking of a freshly prepared Cr(III) solution in aerated conditions. Cr(III) oxidation to Cr(VI) occurred and results ranged between 0.2 and 3 % in all sediment suspensions except for station DMT-109 in which 70 % of the freshly prepared Cr(III) was oxidized. Wadhawan states that aerating the sediments consumes their reductant capacity, which favors Cr(VI) formation. The reduction of sediment reductant capacity upon aeration is due to the rapid loss of AVS and the reduced forms of other key reductants (i.e. iron and manganese). The concentrations of Cr(VI) formed over the duration of these experiments are presented in Figure 5.1.3(e) (Wadhawan 2012). Concentrations of AVS and iron were notably lower at sampling location DMT-109 in comparison to other locations and the sample does not appear characteristic of naturally occurring conditions in the Harbor. Consequently, aerating this sample after amending it with freshly prepared Cr(III) produced the greater percentage of Cr(III) oxidation observed at this location. Despite the lower reducing capacity at this location, Cr(VI) was not formed when sediments were aerated for 30 days (without the addition of Cr(III)). In summary, Wadhawan showed that where no Cr(III) was added to sediments, aeration of the sediments did not yield Cr(VI) (approach 1). Cr(VI) was only formed under conditions of added freshly prepared Cr(IIII) and active aeration of the sediments (approach 2)."

Following these proposed additions, the text should continue with the next paragraph that begins with "For an evaluation of Cr(VI) reoccurrence..." as it is currently written.

Response: After review of the recommendations, MDE has incorporated changes to the document in Section 5.1.3.

9. The commentor states that in Section 5.1.3, the following paragraph could be added before paragraph 2 on page 28:

"The Cr(III) that was produced upon reduction of the added Cr(VI) is freshly prepared Cr(III) which is far more reactive than the aged, weathered and unreactive Cr(III) that is actually present in Baltimore Harbor sediments. The loss of reactivity of aged Cr(III) is dramatic even after 5 days (Wadhawan 2012). The Cr(III) in Harbor sediments is far older and therefore even less reactive. Consequently, despite the finding that minimal oxidation of the fresh Cr(III) occurred in the Wadwahan (2012) study, this result is not representative of natural conditions. Cr(III) present in Baltimore Harbor sediments will remain inert as oxidation reactivity is minimized due to the inactive nature of the aged Cr(III) and the prolonged anoxia that supports a sulfide rich environment."

Response: After review of the recommendations, MDE has incorporated changes to the document in Section 5.1.3.

restated to say:

"Oxidation of Cr(III) to Cr(VI) will not occur from oxygenation during sediment resuspension due to dredging, flood events, and bioturbation under normal conditions in Baltimore Harbor because Wadhawan demonstrated that native Harbor sediments did not oxidize when aerated for up to 30 days (Wadwahan 2012, Page 118). Cr(VI) will not form due to the reduced reactivity of the aged Cr(III) in the sediments and its long-term persistence is governed by the reducing capacity of Baltimore Harbor sediments. Considering all these factors, it is understandable that no significant Cr (VI) was detected in the 'in-situ' Baltimore Harbor sediments and that this will remain so in the future as these conditions persist (Wadhawan 2012)."

Response: After review of the recommendations, MDE has incorporated changes to the document in Section 5.1.3.

11. The commentor recommends the addition of a new section (Section 5.4).

[PROPOSED NEW SECTION] ***"5.4 Supplemental Information on the Geochemical Stability and Toxicity of Chromium in Estuarine Sediments***

The following information is intended to supplement the peer reviewed papers currently summarized in Section 5.1.2 (i.e., Watlington et al. (2007)). The sediments within the Northwest Branch and Bear Creek support a reducing environment indicating that Cr(III), the non-toxic species at levels typically found within the environment, is the predominant form of chromium present within the sediment (MDE 2004). These results are consistent with chromium studies where chromium was determined to be geochemically stable and non-toxic in estuarine, marine and freshwater environments. The following studies and chromium concentrations illustrate that chromium concentrations greater than established SQG's are not toxic:

- *United States Environmental Protection Agency (USEPA 2005) showed that despite concentrations of chromium exceeding 1,700 to 3,000 mg/kg, amphipod mortality in those sediments (5-25%) was no greater than in sediments from reference sites (5-20%).*

- *Becker et al. (2006) evaluated the toxicity and bioavailability of total chromium in sediments of the Hackensack River offshore from the Kearny wetland. The study results showed that measurable concentrations of AVS were associated with low concentrations of Cr(VI) and that chromium toxicity was low in sediments with measurable concentrations of AVS. The maximum no-effect concentration estimated in this study was 1,310 mg/kg; considerably greater than existing ERM SQG of 370 mg/kg.*

· *Besser et al. (2004) evaluated the toxicity of chromium species to the amphipod, H. azteca in fresh water and freshwater sediments. Non-toxic sediments in the Cr(VI) spiking study contained chromium concentrations up to 5,000 mg/kg, presumably as Cr(III), suggesting that Cr(III) has low toxicity in freshwater sediments.*

· *Martello et al. (2007) evaluated chromium geochemistry and bioaccumulation in sediments from a chromium contaminated site. Total chromium and Cr(VI) were measured in sediment and sediment porewater to assess the relationship between sediment geochemistry and chromium speciation. In whole sediments, total chromium and Cr(VI) concentrations ranged from 5 to 9,190 mg/kg dry weight and <0.47 to 31 mg/kg dry weight, respectively. Cr(VI) was not detected in sediment porewater at any of the sampling locations. Concentrations of AVS and other geochemical measurements indicated anoxic, reducing conditions in the majority of sediment samples.*

· *Sorensen et al. (2007) conducted a Sediment Quality Triad (SQT) study consisting of chemical characterization in sediment, sediment toxicity and bioaccumulation testing, and benthic community assessments at a chromium site in the Lower Hackensack River, NJ. Although elevated total chromium concentrations in sediment were the rationale for conducting the investigation, Cr(VI) was not detected in porewater and total chromium levels in sediment porewater were well below the chronic saltwater ambient water quality criteria for Cr(VI) (50 µg/L). Therefore, total chromium was unlikely to contribute to toxicity to benthic organisms* in these laboratory experiments."

Response: While this information provides additional supporting evidence that chromium is not a source of toxicity, these studies were conducted in regions outside of the Northwest Branch and Bear Creek for which this WQA was developed. Geochemical properties of sediments from these studies may not be representative of conditions found within the Northwest Branch and Bear Creek and potentially differ in their influence on chromium chemistry. The primary function of this WQA is to demonstrate that chromium present within the sediments of these tidal segments is not a source for toxicity. Therefore MDE has elected not to include this information in the document.

12. The commentor states that the WQA fails to adequately consider the potential for significant ongoing chromium discharges from contaminated stormwater and groundwater at the Harbor Point / Chrome Works redevelopment site.

The commentor states that the continuing redevelopment of the Harbor Point / Chrome Works site could result in additional chromium discharges into Baltimore Harbor from contaminated groundwater and stormwater. During the 1980s, large quantifies of chromium were migrating from this site as a result of the Baltimore Chrome Works operations. The commentor references a consent decree entered into in 1989 by the EPA and MDE with Allied (Honeywell's predecessor) requiring it to investigate

collects contaminated groundwater. Under the consent decree, Honeywell must conduct continuing environmental monitoring to ensure that containment is maintained.

The commentor states that the WQA does not discuss or analyze any of the monitoring data for the Chrome Works site and that without analyzing the current groundwater and surface water conditions at the Chrome Works, the WQA cannot adequately consider the potential effects that this site may continue to have on the Baltimore Harbor. MDE should revise the draft WQA to consider recent groundwater and surface water monitoring data from this site.

The commentor states that the developers of the Harbor Point project intend to pierce the protective cap during the redevelopment which conflicts with earlier statements that the cap would not be disturbed during the redevelopment. This raises concerns regarding additional air and water pollution resulting from exposing contaminated soils that are currently encapsulated and that MDE should not re-categorize the Northwest Branch impairment until the construction on this project has been completed and subsequent environmental monitoring data have been collected and analyzed. In summary, the commentor states that the current WQA fails to consider existing and potential pollution discharges from the Harbor Point / Chrome Works site, and it is therefore inadequate.

Response: This WQA establishes that chromium present in the water column and sediment of the Northwest Branch and Bear Creek portions of the Patapsco River Mesohaline Chesapeake Bay segment is not an impairing substance and toxicity present within the sediments is not due to chromium contamination. This WQA fully acknowledges that ongoing sources of chromium enter the waters of Northwest Branch and Bear Creek, though under existing conditions the chromium from these discharges (groundwater and storm water) does not impair water quality as chromium present in the ambient water column and sediment is found predominantly in its non-toxic trivalent state [Cr (III)]. As demonstrated within this WQA, under existing conditions, chromium has no impact on the health of the aquatic community inhabiting the water column and sediment and is supportive of the "protection of aquatic life" designated use. This WQA establishes that chromium is not an impairing substance and may be removed from Category 5 of Maryland's Integrated Report.

Honeywell entered into a consent decree on September 29, 1989 with EPA and MDE which required the company to fully investigate the environmental impact of releases from the site, and implement remedial measures approved by State and Federal agencies. Remedial activities were completed in 1999. Under the consent decree Honeywell is required to conduct surface water and ground water sampling quarterly to ensure that chromium contamination is fully contained by these remedial practices and does not impact water quality adjacent to the site. Quarterly monitoring requires collection of water column samples one foot below the surface

dissolved chromium. Water quality data from quarterly reports over the last four quarters, beginning in the 1st quarter of 2012, found that total dissolved chromium concentrations for all samples were well below the freshwater aquatic life chronic criterion for Cr (VI) of 11 ppb.[1] Therefore, surface water discharges of chromium from Harbor Point do not impair the water column. Please note that this information has been included in the comment response to address the commentor's concern over the potential impacts of ongoing sources of chromium from Harbor point but will not be presented within the body of the WQA.

While groundwater samples are also collected quarterly and analyzed for total dissolved chromium as required under the consent decree, this data is not useful for assessment purposes as groundwater monitoring wells are not representative of ambient water quality in the Northwest Branch to which aquatic life is exposed. Therefore water quality data from groundwater is not included in this assessment. Furthermore, the surface water quality data demonstrates that no chromium impairment exists, indicating that groundwater sources do not impact ambient water quality. A head maintenance system is in operation designed to extract contaminated groundwater from sixteen (16) wells located within the hydraulic barrier, lowering groundwater levels within the barrier to elevations less than that of the Patapsco River, and thereby reducing releases of chromium to the river from any imperfections in the wall. Contaminated groundwater collected by this system is temporarily stored on-site in two 10,000 gallon tanks and then transported from the site to a hazardous waste treatment facility.[2]

In regards to concerns over potential releases of chromium in the future due to the construction of Exelon's new headquarters at Harbor Point, the construction plans are currently being reviewed by the Land Management Administration at MDE and EPA. It is anticipated that these plans will incorporate measures for addressing potential releases from the site to ensure chromium discharges do not impact water quality. Quarterly monitoring of surface water will also continue during and after construction activities are completed as required under the consent decree. The necessary steps will be implemented to ensure chromium contamination is contained during construction. As it is only speculation as to whether chromium releases in the future will impact water quality, a delay in release of the WQA would not be warranted. A WQA is solely based on existing conditions and cannot predict potential changes in water quality due to future activities. If in the future it is determined that chromium is an impairing substance, the Northwest Branch will be relisted and addressed.

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[1] CH2MHILL. 2012. Baltimore Inner Harbor Environmental Media Monitoring Plan. Chantilly, VA. Quarterly Report No. 90-94

[2] MDE. 2013a. Fact Sheet: Allied/Honeywell Site at Inner Harbor. Baltimore, MD: Maryland Department of the Environment. Also available at: http://www.mde.state.md.us/assets/document/waste/Allied_Honeywell_fact_sheet_long_version.pdf

significant ongoing chromium discharges from contaminated stormwater and groundwater at Dundalk Marine Terminal (DMT) into Bear Creek and Baltimore Harbor. Although Chromium mitigation at the DMT is occurring through a storm drain relining project, the commentor asserts that discharges will continue to occur until the mitigation is complete and that comprehensive monitoring will be required to ensure that the corrective measures will prevent future discharges of chromium laden stormwater. Until that monitoring is complete, MDE will lack sufficient data to conclude that DMT is not contributing to toxic chromium discharges into the receiving waters. In summary, the commentor states that MDE should not de-list the impairments until this monitoring data has been collected, analyzed, and incorporated into an adequate water quality analysis.

Response: Surface water and groundwater discharges from the Dundalk Marine Terminal do not transport into the waters of the Northwest Branch or Bear Creek for which this WQA was developed to address the chromium listings. Therefore it is not necessary to address sources of chromium for this facility in the WQA. Furthermore, please refer to the response to comment 12 in the first paragraph for information explaining that chromium discharges from ongoing sources do not impair the waters of Northwest Branch and Bear Creek.

In addition, this WQA did reference the Ecological Risk Assessment for Dundalk Marine Terminal as supporting evidence for establishing that chromium is not an impairing substance. Chromium discharges from this site do not cause levels in ambient water quality to exceed applicable criteria supportive of the "protection of aquatic life" designated use. The Ecological Risk assessment did not identify chromium as a contaminant of concern for further investigation. Please refer to Section 5.3 for more detailed information.

MDE also requires ongoing monitoring of the water discharges from the various stormwater discharge points at Dundalk Marine Terminal. The Maryland Port Administration submits NPDES discharge reports to the Water Management Administration. A water treatment plant will continue operating at Dundalk Marine Terminal. This plant removes chromium from stormwater and groundwater entering into the 14th and 15th Street storm drains that run through the Dundalk Marine Terminal where chromium ore processing residue (COPR) materials were deposited. The plant will remain operational until the storm drain repair and relining project is completed. The project completion is anticipated by the end of 2015. Once the remedial measures are completed, a three-year, enhanced groundwater monitoring plan will be implemented to determine whether the overall containment is effective or the remedial measures must be amended. Nonetheless, it is reasonably anticipated that some level of stormwater and groundwater releases are expected to continue until remedial measures are completed.

Point/Chrome Works sites, many other sites throughout the Baltimore Harbor watershed contain potentially contaminated sediments. In summary, the commentor states that until MDE investigates the other sites that potentially contain chromium contamination and studies the extent of chromium laden discharges from those sites, it will be unable to adequately determine the extent to which existing discharges are affecting Bear Creek and the Northwest Branch.

Response: Please refer to the response to comment 12 in the first paragraph for information explaining that chromium discharges from ongoing sources do not impair the waters of Northwest Branch and Bear Creek.

In addition MDE's Land Restoration Program's (LRP) COPR Initiative funded through a cooperative agreement with the EPA has conducted preliminary assessments/investigations of sites which have historically applied COPR as landfill material for disposal. The LRP has identified several locations where such materials may have been used as fill material. To date, LRP's investigations have determined that these sites do not require additional investigation.

15. The commentor states that the WQA fails to adequately consider the potential for conversion of trivalent chromium to hexavalent chromium through frequent dredging and storm events, and that even if the resulting hexavalent chromium reverts to trivalent chromium within a few days or even a few hours after sediments are disturbed, aquatic organisms can still be exposed to toxic hexavalent chromium until the reversion process is complete. Every occurrence of dredging in the Harbor and every storm event in the Baltimore area provides an opportunity for conversion of trivalent chromium to hexavalent chromium and that the WQA does not consider the frequency of these events, and the extent to which frequent sediment disturbances can cause toxic chromium conditions in the Northwest Branch and Bear Creek. In summary, the commentor states that MDE should not de-list these chromium impairments until the potential for toxic chromium pollution due to sediment disturbance in the Baltimore Harbor is fully understood.

Response: The language referred to in this comment has been revised within Section 5.1.3 in paragraph 3 of page 29 to state "Oxidation of Cr (III) to Cr (VI) will not occur from oxygenation during sediment resuspension due to dredging, flood events, and bioturbation under existing conditions in the Baltimore Harbor." While minimal oxidation of Cr (III) occurred under laboratory conditions in which Cr (VI) additions were oxidized upon aeration following complete reduction to Cr (III), only the freshly produced Cr (III) from the addition underwent this conversion. The dissertation by Amar Wadhawan of the JHU CTFR under the direction of Dr. Edward Bouwer referenced in section 5.1.3 of the WQA demonstrated that oxidation of background Cr (III) in Baltimore Harbor sediments when oxygenated for up to 720 hours is found to be insignificant as Cr (VI) formation did not occur. The oxygenation period is highly conservative in

Baltimore Harbor sediments does not have the potential to form Cr (VI) during sediment resuspension under existing conditions. Please refer to section 5.1.3 for additional information. See also response to comment #5.

16. The commentor states that re-categorizing these impairments at this time places a burden on citizen groups to collect additional water quality data. Citizen groups that have limited resources would need to perform extensive testing near DMT, Harbor Point, and other locations to monitor the chromium levels. Such water quality testing is expensive; testing in a legally defensible, comprehensive and statistically meaningful manner could easily cost thousands of dollars.

In summary, the commentator states that given the timing of the projects at DMT and Harbor Point and the continuing investigation of other sites, it would be far more efficient and protective of water quality to maintain the current TMDL categorization for these impairments at this time. With active sources of chromium pollution and the possible disturbance of soils at the Chrome Works site, this is not an appropriate time to remove these impairments from the list of waters for which a TMDL must be developed.

Response: Please refer to the response to comment 12 in the first paragraph for information explaining that chromium discharges from ongoing sources do not impair the waters of Northwest Branch and Bear Creek. As this WQA establishes that chromium is not an impairing substance and may be removed from Category 5 of Maryland's Integrated Report, there is no need for citizen groups to collect additional water quality data to characterize levels of chromium in the Northwest Branch and Bear Creek. In addition, the responses to comments 13, 14, and 15 also explain that monitoring of chromium discharges in storm water and ground water will continue at Harbor Point and DMT and Land Restoration Program's COPR Initiative determined that sites where the COPR material was land applied do not require additional investigation. This further suggests that citizen groups would not be required to conduct monitoring of chromium. MDE will continue to assess water quality of the Baltimore Harbor from ongoing monitoring activities to ensure chromium contamination from ongoing sources do not impact water quality. If in the future chromium levels exceed applicable criterion in ambient water resulting in an impairment, the Northwest Branch or Bear Creek would be relisted.

Creek Portions of the Patapsco River Mesohaline Tidal Chesapeake Bay Segment, Baltimore City and Baltimore County, Maryland

Comments from
Steve Stewart, Kevin Brittingham and Erin Wisnieski

Baltimore County
Department of Environmental Protection and Sustainability

May 9, 2013

- **There are two mentions of the Trash TMDL (Exec. Summary and Intro) does MDE still plan to submit it to EPA in 2013?**

- **p. 19 mention of 3210 as highest spiking level, but there is a 4180 as well**

- **p. 31 end of 2nd P; mention of fresh sediment burying "historically contaminated sediments", brings to mind questions: How are the sediment samples taken/ how deep into the sediment? Would sediments at different depths have different Cr levels? (Could have consequence of dredging, storm activity, etc.)**

- **Were synergistic effects included? If not, it should be included in future investigations.**

May 14, 2013

Mr. Tony Allred
Maryland Department of the Environment (MDE)
1800 Washington Blvd., Suite 540
Baltimore, MD 21230

Subject: Review of Maryland Department of the Environment *"Water Quality Analysis (WQA) of Chromium in Northwest Branch and Bear Creek Portions of the Patapsco River Mesohaline Tidal Chesapeake Bay Segment, Baltimore City and Baltimore County, Maryland."* (April 2013).

Dear Mr. Allred,

On behalf of the Maryland Port Administration and Honeywell International Inc., ENVIRON has reviewed the MDE "*Water Quality Analysis of Chromium in Northwest Branch and Bear Creek Portions of the Patapsco River Mesohaline Tidal Chesapeake Bay Segment, Baltimore City and Baltimore County, Maryland." (April 2013*).

The 2013 Water Quality Assessment (WQA) is well organized, clearly written, and provides a very good summary of available information. MPA, Honeywell, and ENVIRON concur with the overall findings of all studies presented in the 2013 WQA that chromium is not a source of toxicity in the water column and sediments of Northwest Branch and Bear Creek and therefore, the protection of the aquatic life designated use is not impaired by chromium.

There are some focused areas of the narrative that could be enhanced to support the technical findings of the WQA. Supporting information is provided covering the following topics:

I. The 2013 WQA correctly cites the UMD TIE. While the UMD study was inconclusive on the compounds causing toxicity, the UMD provided a substantial amount of information showing that chromium was not the cause of toxicity.

II. The 2013 WQA does a very good job summarizing the Johns Hopkins University Studies overall. There is one element of the Wadhawan (2012) dissertation that merits further amplification because of its importance to the story of potential Cr(VI) oxidation.

III. The 2013 WQA summarized much of the peer reviewed literature. We have cross-indexed the MDE compilation with references ENVIRON has identified and recommend the addition of a new section (Section 5.4) to augment this discussion.

Supporting documentation concerning the three topics enumerated above is attached for your consideration. We appreciate the opportunity to provide comments on the 2013 WQA and are available to further discuss any aspects of these suggestions.

Please contact us at your earliest convenience if we can provide any additional information or assistance.

Sincerely,

Mary Sorensen, CE
Senior Science Advisor

cc:

Mark Kreafle, Maryland Port Administration
Bob Munroe, Maryland Port Administration
Chris French, Honeywell
Michael Daneker, Arnold and Porter

Attachment A

Specific Comments on 2013 WQA

regarding the toxicity of metals in Baltimore Harbor sediments; therefore EPA did not approve the delisting decision supported by the Chromium WQA submitted in 2004.

This section would be improved with the addition of the following information at the conclusion of Section 5.1.1 (page 22):

> While the TIE was inconclusive in regard to implicating a particular metal or group of metals for the toxicity observed in Bear Creek / Northwest Branch, UMD provided a substantial amount of information showing that chromium was not the cause of toxicity via partition to porewater or via bulk sediment exposure.

Additional supporting information that MDE can review in support of the suggested language mentioned above is provided in Attachment B.

II. Section 5.1.3; Page 25 Paragraph 2: Evaluation of Cr(III) Oxidation

The interpretation of the Wadhawan (2012) study is correctly summarized in the 2013 WQA. There are results that could be emphasized in support of the 2013 WQA conclusions. Note that in the first paragraph below, Wadhawan did not include certain key data (described as "data not shown") regarding the natural conditions in Baltimore Harbor.. Our personal communications with Mr. Wadhawan in May of 2013 confirmed that Section 4 of Wadhawan (2012) does not mention the 30-day aeration period for unspiked sediments. However, this detail is subtly mentioned in Section 5 (Page 118, cited in more detail below). Mr. Wadhawan mentioned that the 30-day aeration of unspiked sediments is included in a manuscript of this work that he recently submitted for publication (personal communication between Mary Sorensen and Amar Wadhawan, May 2013). We recommend that the two paragraphs beginning on Page 25 (Paragraph 2) and continuing on to Page 27 (Paragraph 1) in the MDE 2013 WQA be replaced with the following three paragraphs (note that Page 26 contains figures only which would be retained as they are called out here or earlier):

> Wadhawan (2012) performed multiple experiments to evaluate the potential for chromium to oxidize from Cr(III) to Cr(VI). One experiment evaluated the potential for Cr(III) oxidation under anaerobic conditions, which is the predominant state of in-situ sediments. Cr(III) was added to Baltimore Harbor sediments that were maintained in an anaerobic condition. Addition of Cr(III) to anaerobic sediments resulted in no formation of Cr(VI) in any of the samples from multiple batch experiments (Wadhawan, Page 79, Paragraph 1 and page 87 Paragraph 1). A second experiment evaluated the potential for Cr(III) to oxidize to Cr(VI) under aerobic conditions, in which the sediment suspension was actively oxygenated using two approaches: (1) without the addition of Cr(III) and (2) with the addition of a laboratory grade, freshly prepared Cr(III) aqueous solution. With regard to approach (1), Wadhawan states that "Oxidation of background Cr(III) in sediments was insignificant as experimental controls of unspiked sediment suspensions did not show Cr(VI) formation upon aeration (data not shown)"(Wadhawan 2012, Page 87). The data that is not shown is that approach 1 involved the aeration of each of the Harbor sediment samples for up to 30 days, or 720 hours, as noted by Wadwahan (2012, Page 118). The experimental aeration period is very conservative in terms of reflecting the natural conditions of Baltimore Harbor where stable sediments could be aerated from potential dredging, flood events, and bioturbation. Cr(VI) was not detected and the lack of Cr(VI) from these Harbor sediment

samples indicate that Cr(VI) formation due to sediment suspension will not occur under normal conditions in Baltimore Harbor.

The oxidation of Cr(III) to Cr(VI) was further evaluated by Wadhawan (2012) using approach (2) through the spiking of a freshly prepared Cr(III) solution in aerated conditions. Cr(III) oxidation to Cr(VI) occurred and results ranged between 0.2 and 3 % in all sediment suspensions except for station DMT-109 in which 70 % of the freshly prepared Cr(III) was oxidized. Wadhawan states that aerating the sediments consumes their reductant capacity, which favors Cr(VI) formation. The reduction of sediment reductant capacity upon aeration is due to the rapid loss of AVS and the reduced forms of other key reductants (i.e. iron and manganese). The concentrations of Cr(VI) formed over the duration of these experiments are presented in Figure 5.1.3(e) (Wadhawan 2012). Concentrations of AVS and iron were notably lower at sampling location DMT-109 in comparison to other locations and the sample does not appear characteristic of naturally occurring conditions in the Harbor. Consequently, aerating this sample after amending it with freshly prepared Cr(III) produced the greater percentage of Cr(III) oxidation observed at this location. Despite the lower reducing capacity at this location, Cr(VI) was not formed when sediments were aerated for 30 days (without the addition of Cr(III)). In summary, Wadhawan showed that where no Cr(III) was added to sediments, aeration of the sediments did not yield Cr(VI) (approach 1). Cr(VI) was only formed under conditions of added freshly prepared Cr(IIII) *and* active aeration of the sediments (approach 2).

Following these proposed additions, the text should continue with the next paragraph that begins with "For an evaluation of Cr(VI) reoccurrence..." as it is currently written.

Section 5.1.3; Page 27-28: Evaluation of Cr(VI) Reoccurrence

The following paragraph could be added before paragraph 2 on page 28:

The Cr(III) that was produced upon reduction of the added Cr(VI) is freshly prepared Cr(III) which is far more reactive than the aged, weathered and unreactive Cr(III) that is actually present in Baltimore Harbor sediments. The loss of reactivity of aged Cr(III) is dramatic even after 5 days (Wadhawan 2012). The Cr(III) in Harbor sediments is far older and therefore even less reactive. Consequently, despite the finding that minimal oxidation of the fresh Cr(III) occurred in the Wadwahan (2012) study, this result is not representative of natural conditions. Cr(III) present in Baltimore Harbor sediments will remain inert as oxidation reactivity is minimized due to the inactive nature of the aged Cr(III) and the prolonged anoxia that supports a sulfide rich environment.

Section 5.1.3; Page 28 Paragraph 2: *While oxidation of Cr(III) to Cr(VI) may occur from oxygenation during sediment resuspension due to dredging, flood events, and bioturbation, the potential for Cr(VI) formation is dependent on the reactivity of existing Cr(III) in the sediments and its long-term persistence is governed by sediment reducing capacity...*

Based on information obtained directly from Wadhawan (2012) (and provided in the earlier comments), this paragraph should be restated to say:

Oxidation of Cr(III) to Cr(VI) will not occur from oxygenation during sediment resuspension due to dredging, flood events, and bioturbation under normal conditions in Baltimore Harbor because Wadhawan demonstrated that native Harbor sediments did not oxidize when aerated for up to 30 days (Wadwahan 2012, Page 118). Cr(VI) will not form due to the reduced reactivity of the aged

Baltimore Harbor sediments. Considering all these factors, it is understandable that no significant Cr (VI) was detected in the 'in-situ' Baltimore Harbor sediments and that this will remain so in the future as these conditions persist (Wadhawan 2012).

III. [PROPOSED NEW SECTION] Section 5.4; Page 34: Summary of Peer Reviewed Scientific Literature on Chromium Geochemical Stability and Toxicity in Estuarine Sediments.

We recommend the addition of a new section to support the current state of the science regarding the inherent lack of toxicity and geochemically stability of Cr(III) in sediments.

We suggest the following text be added as a new Section 5.4 of the 2013 WQA:

5.4 Supplemental Information on the Geochemical Stability and Toxicity of Chromium in Estuarine Sediments

The following information is intended to supplement the peer reviewed papers currently summarized in Section 5.1.2 (i.e., Watlington *et al.* (2007)). The sediments within the Northwest Branch and Bear Creek support a reducing environment indicating that Cr(III), the non-toxic species at levels typically found within the environment, is the predominant form of chromium present within the sediment (MDE 2004). These results are consistent with chromium studies where chromium was determined to be geochemically stable and non-toxic in estuarine, marine and freshwater environments. The following studies and chromium concentrations illustrate that chromium concentrations greater than established SQG's are not toxic:

- United States Environmental Protection Agency (USEPA 2005) showed that despite concentrations of chromium exceeding 1,700 to 3,000 mg/kg, amphipod mortality in those sediments (5-25%) was no greater than in sediments from reference sites (5-20%).
- Becker *et al.* (2006) evaluated the toxicity and bioavailability of total chromium in sediments of the Hackensack River offshore from the Kearny wetland. The study results showed that measurable concentrations of AVS were associated with low concentrations of Cr(VI) and that chromium toxicity was low in sediments with measurable concentrations of AVS. The maximum no-effect concentration estimated in this study was 1,310 mg/kg; considerably greater than existing ERM SQG of 370 mg/kg.
- Besser *et al.* (2004) evaluated the toxicity of chromium species to the amphipod, *H. azteca* in fresh water and freshwater sediments. Non-toxic sediments in the Cr(VI) spiking study contained chromium concentrations up to 5,000 mg/kg, presumably as Cr(III), suggesting that Cr(III) has low toxicity in freshwater sediments.
- Martello *et al.* (2007) evaluated chromium geochemistry and bioaccumulation in sediments from a chromium contaminated site. Total chromium and Cr(VI) were measured in sediment and sediment porewater to assess the relationship between sediment geochemistry and chromium speciation. In whole sediments, total chromium and Cr(VI) concentrations ranged from 5 to 9,190 mg/kg dry weight and <0.47 to 31 mg/kg dry weight, respectively. Cr(VI) was not detected in sediment porewater at any of the sampling locations. Concentrations of AVS and other geochemical measurements indicated anoxic, reducing conditions in the majority of sediment samples.

- Sorensen *et al.et al.* (2007) conducted a Sediment Quality Triad (SQT) study consisting of chemical characterization in sediment, sediment toxicity and bioaccumulation testing, and benthic community assessments at a chromium site in the Lower Hackensack River, NJ. Although elevated total chromium concentrations in sediment were the rationale for conducting the investigation, Cr(VI) was not detected in porewater and total chromium levels in sediment porewater were well below the chronic saltwater ambient water quality criteria for Cr(VI) (50 µg/L). Therefore, total chromium was unlikely to contribute to toxicity to benthic organisms in these laboratory experiments.

References Cited:

Becker D.S., Long, E.R., Proctor, D.M., Ginn, T.C. 2006. Evaluation of potential toxicity and bioavailability of chromium in sediments associated with chromite ore processing residue. Environ. Toxicol. Chem. 25:2576-2583

Besser, J.M., W.G. Brumbaugh, N.E. Kemble, T.W. May, and C.G. Ingersoll. 2004. Effects of sediment characteristics on the toxicity of chromium(III) and chromium(VI) to the amphipod, Hyalella azteca. Environ. Sci. Technol. 38:6210-6216.

Martello, L.B., Sorensen, M.T., P.C. Fuchsman, and R.J. Wenning, 2007. Chromium geochemistry and bioaccumulation in sediments from the lower Hackensack River, New Jersey. Archives of Environmental Contamination and Toxicology, 53:337-350.

Maryland Department of the Environment (MDE). 2004. Water Quality Analyses of Chromium in the Inner Harbor/Northwest Branch and Bear Creek Portions of Baltimore Harbor in Baltimore City and Baltimore County, Maryland.

Sorensen M.T., Conder, J.M., Fuchsman, P.C., Martello, L.B., Wenning, R.J. 2007. Using a sediment quality triad approach to evaluate benthic toxicity in the Lower Hackensack River, New Jersey. Arch. Environ. Contam. Toxicol. 53:36-49.

United States Environmental Protection Agency (USEPA), 2005. Procedures for the Derivation of Equilibrium Partitioning Sediment Benchmarks (ESBs) for the Protection of Benthic Organisms: Metals Mixtures. EPA-600-R-02-001. Office of Research and Development.

Wadhawan, A. 2012. Geochemical Influences on Chromium Speciation and Fate in Estuarine Sediments; Importance of Redox Interactions with Manganese Sulfide Minerals. Baltimore, MD: Johns Hopkins University.

Watlington, K., Graham, A., and Bouwer, E. 2007. The Sediment Ingestion Pathway as a Source of Toxicity in the Baltimore Harbor. Baltimore, MD: Johns Hopkins University, Department of Geography and Environmental Engineering.

Attachment B

Supporting Information

Attachment B: UMD TIE Study Supplemental Information

The UMD TIE provided substantial evidence that chromium was not the cause of toxicity (Klousterhaus *et al.* 2007). UMD reported that chromium concentrations among the sites sampled ranged from 127 mg/kg to 967 mg/kg and concentrations of total chromium in sediment porewater was even lower than the most conservative freshwater or saltwater criteria for Cr(VI) and lower than the most conservative freshwater criteria for Cr(III) (no criteria are available for Cr(III) in saltwater due to its inherent lack of toxicity). Specific findings by UMD illustrating that chromium is not responsible for any observed toxicity in the TIE study are as follows:

- The metals analysis indicated that porewater concentrations of chromium and other metals were below acute ambient water quality criteria in all of the sediments tested. The only metal that was measured in porewater above the criteria was copper (UMD TIE page 111; paragraph 2).
- Locations with concentrations of total chromium as high as 929 mg/kg in bulk sediment (BSM 28) had 80 to 100 percent amphipod survival in 24, 48, and 72 hour toxicity tests (UMD TIE page 63; Figure 4-19 – shown below).
- The SEM/AVS ratio in these sediments was three to four orders of magnitude below the value of 1, indicating that there should be no sediment toxicity due to porewater metals (i.e., according to USEPA 2005; page 46; Table 2-7).
- The sum of interstitial water benchmark units (ΣIWBUs) in the UMD study for all metals excluding copper was less than 1, indicating toxicity would not be expected from metals (page 115; paragraph 1).
- The IWBU for chromium in the TIE sediments was less than 1 for all but one station. Although this station had an IWBU above 1 it was not toxic in the whole sediment toxicity test. As such, the authors concluded that the sediments should not be toxic due to chromium in the porewater (UMD TIE Page 116;paragraph 1).

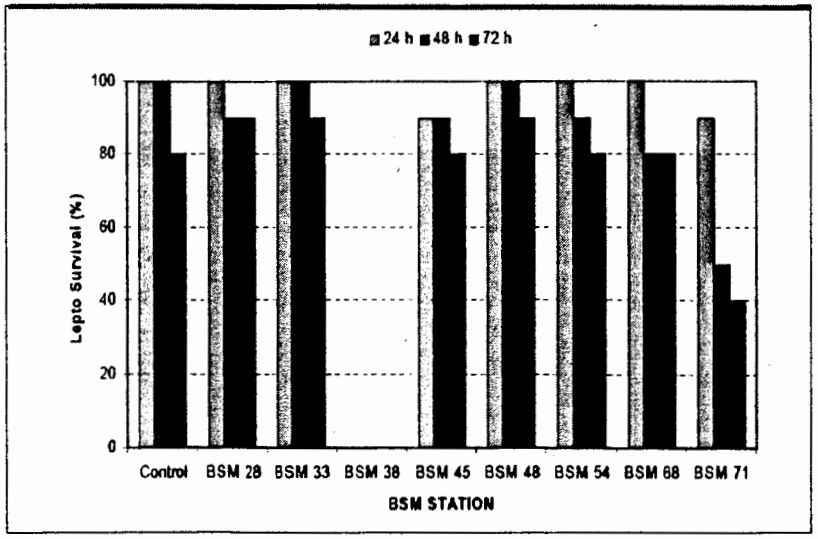

Figure 4-19 (UMD 2007). Cumulative toxicity of pore water to *L. plumulosus* during a 24, 48 and 72 hour exposure. Note Location BSM 28 with a total chromium concentration as high as 929 mg/kg in bulk sediment had 80 to 100 percent amphipod survival.

References Cited:

Klousterhaus, S., Baker, J., Zeigler, G., and Fisher, D. 2007. Toxicity Identification and Evaluation and Long-Term Contaminant Trends in the Baltimore Harbor. Solomons, MD: University of Maryland Center for Environmental Science, Chesapeake Biological Laboratory.

USEPA 2005. U.S. EPA Decision Rationale for "Water Quality Analyses of Chromium in the Inner Harbor/Northwest Branch and Bear Creek Portions of Baltimore Harbor in Baltimore City and Baltimore County, Maryland.". Philadelphia, PA: US Environmental Protection Agency, Region III.

BALTIMORE HARBOR WATERKEEPER®
A PROGRAM OF BLUE WATER BALTIMORE

Via Electronic and First Class Mail

May 15, 2013

Anthon V. Allred, Jr.
TMDL Technical Development Program
Department of the Environment
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Dear Mr. Allred:

These comments, regarding the April 12, 2013 Draft Water Quality Analysis of Chromium in Northwest Branch and Bear Creek Portions of the Patapsco River Mesohaline Tidal Chesapeake Bay Segment ("the WQA"), are submitted by Blue Water Baltimore, Inc., a grassroots environmental organization dedicated to restoring the quality of Baltimore's rivers, streams and Harbor to foster a healthy environment, a strong economy, and thriving communities. Specifically, the Baltimore Harbor WATERKEEPER ("BHWK") program of Blue Water Baltimore is dedicated to stopping water pollution in the Baltimore Harbor watershed through the use of advocacy, enforcement, and education. Members of Blue Water Baltimore use and enjoy waters affected by the WQA, including the Northwest Branch and Bear Creek within the Baltimore Harbor/ Patapsco River watershed.

The Northwest Branch and Bear Creek have been listed as impaired for chromium on the federal 303(d) list since 1998, based on direct measurements of chromium levels in sediments.

5, for which TMDLs are required. *Id.*

The WQA states that, upon approval from the U.S. Environmental Protection Agency ("EPA"), the Maryland Department of the Environment ("MDE") intends to use the WQA to support re-categorizing the chromium impairment in the Northwest Branch and Bear Creek Portions of the Patapsco River (the "Watershed") from Category 5 to Category 2 ("water bodies meeting some water quality standards but with insufficient data and information to determine if other water quality standards are being met"). 2010 Integrated Report, Part A at 12. Such a re-categorization would prevent the development of chromium TMDLs for waters unless new data conclusively demonstrate an impairment and therefore necessitates a relisting of the watershed as Category 5.

BHWK is concerned that this re-categorization could further degrade the water quality in Bear Creek and the Northwest Branch of the Patapsco River. The WQA focuses only on the potential toxicity of chromium laden sediments in the Baltimore Harbor and ignores active sources of additional chromium discharges. Additionally, re-categorizing these impairments at this time places a burden on citizen groups to collect more water quality data over the next few years, as significant remediation and development activities occur within the Harbor watershed, in order to ensure that the impairment does not in fact persist.

1. **The WQA fails to adequately consider the potential for significant ongoing chromium discharges from contaminated stormwater and groundwater at the Harbor Point / Chrome Works redevelopment site.**

The continuing redevelopment of the Harbor Point / Chrome Works site could result in additional chromium discharges into Baltimore Harbor from contaminated groundwater and stormwater. Harbor Point is a Resource Conservation and Recovery Act ("RCRA") redevelopment of the former Baltimore Chrome Works. *See* EPA, Honeywell Baltimore Inner Harbor, Status 09/29/2012.[2] Honeywell and other operators processed chromium ore at the Site from the mid-nineteenth century through 1985. *Id.* From 1967 to 1986, the Chrome Works

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[1] Available at http://www.mde.maryland.gov/programs/water/tmdl/integrated303dreports/pages/final_approved_2010_ir.aspx

[2] Available at http://www.epa.gov/reg3wcmd/ca/md/pdf/mdd069396711.pdf.

produced about 100,000 cubic yards of chromium ore processing residue ("COPR") per year. *See* MDE, Facts About Chromium Ore Processing Residue (COPR) Site Initiative.[3] Throughout the twentieth century, much of the COPR generated at Chrome Works was deposited at areas of the Dundalk Marine Terminal ("DMT"), currently owned by the Maryland Port Administration. *Id.* Multiple other sites in the Baltimore area received COPR, and, as of 2009, MDE was investigating 44 sites for COPR contamination. *Id.*

Environmental investigations conducted at the Chrome Works site during the 1980's "established that large quantities of chromium, calculated to be approximately 62 pounds per day, were migrating from the site, with most of the chromium being released to the Baltimore harbor." MDE, Facts About Allied/Honeywell Site at Inner Harbor.[4] Approximately 80% of this chromium pollution was in the toxic hexavalent form. *Id.* In 1989 EPA and MDE entered into a consent decree with Allied (Honeywell's predecessor) requiring it to investigate, remedy, and control chromium discharges from the site. *Id.* Allied installed a perimeter slurry wall, a multi-layer cap over the site, and a head maintenance system which collects contaminated groundwater. *Id.*

Under the consent decree, Honeywell must conduct continuing environmental monitoring to ensure that containment is maintained. EPA, Honeywell Baltimore Inner Harbor, Status 09/29/2012 at 2. However, the WQA does not discuss or analyze any of the monitoring data for the Chrome Works site. Without analyzing the current groundwater and surface water conditions at the Chrome Works, the WQA cannot adequately consider the potential effects that this site may continue to have on the Baltimore Harbor. At the very least, MDE should revise the draft WQA to consider recent groundwater and surface water monitoring data from this site.

Moreover, it has recently been revealed that the developers of the Harbor Point project intend to pierce the protective cap during the redevelopment. *See* Maryland Daily Record,

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[3] Available at http://www.mde.state.md.us/assets/document/Chromium%20Ore%20Processing%20Residue.pdf

[4] Available at http://www.mde.state.md.us/programs/Land/HazardousWaste/HazardousWasteHome/Document

drive pilings 70 to 80 feet into the ground in order to construct a 23 story office tower for the new Exelon Corp. headquarters at Harbor Point. *Id.* This proposal conflicts with earlier statements by the Mayor of Baltimore City that the cap would not be disturbed during the redevelopment. *Id.*

This proposal raises serious concerns regarding additional air and water pollution resulting from exposing contaminated soils that are currently encapsulated. Given the timing of this redevelopment project, MDE should not re-categorize the Northwest Branch impairment until the construction has been completed and subsequent environmental monitoring data have been collected and analyzed. The current WQA fails to consider existing and potential pollution discharges from the Harbor Point / Chrome Works site, and it is therefore inadequate.

2. **The WQA fails to adequately consider the potential for significant ongoing chromium discharges from contaminated stormwater and groundwater at Dundalk Marine Terminal.**

In 2006 MDE entered into a consent decree with Honeywell International, Inc. and the Maryland Port Administration ("MPA") regarding pollution caused by COPR placed at the Dundalk Marine Terminal ("DMT"). *See State of Maryland v. Honeywell Int'l, Inc.*, Consent Decree (Cir. Ct. Balt. Cnty., Apr. 2006).[6] Chromium leachate at DMT has infiltrated groundwater and storm drain systems that pass through the COPR. *Id.* at 2. The 2006 consent decree is the most recent attempt to control discharges of hazardous substances at the site. In 1992 MDE and the Maryland Port Administration entered into an earlier consent decree "to address the release or threatened release of hazardous substances from the DMT." *Id.* at 2. The 1992 consent decree required collection and treatment of groundwater and mitigation of "offsite transport of hexavalent chromium." *Id.* at 3. Despite installing catch basins, backflow preventers, extraction wells, and a wastewater treatment plant designed to reduce the offsite migration of chromium, "additional actions . . . are needed to evaluate and address the presence of chromium at the DMT, including the transport of chromium in Stormwater and Groundwater

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[5] Available at: http://thedailyrecord.com/wp-content/plugins/tdc-sociable-toolbar/wp-print.php?p=233407

[6] available at http://www.mde.state.md.us/programs/Land/MarylandBrownfieldVCP/ERRP_Superfund/Documents/Consent_Decree.pdf

at the Site and its effect in Surface Waters and sediments of the Patapsco River." 2006 Consent Decree at 3–4.

Pursuant to the 2006 consent decree, in 2011 MPA and Honeywell submitted to MDE a Corrective Measures Alternatives Analysis ("CMAA") containing several options for remediating the site. In July 2012 MDE determined that the remediators should implement "Alternative 3" from the CMAA, which involves relining storm drains and designing and installing a "long-term monitoring and site maintenance plan to assure that discharges of contaminants of concern are positively reduced or eliminated." MDE Ltr. re MPA/Honeywell – Corrective Measures Alternatives Analysis, DMT at 1.[7] As of July 2012, the remediators had only completed a two-year "pilot project to reline the storm drains" at DMT. *Id.*

In selecting Alternative 3, MDE imposed additional conditions requiring MPA and Honeywell to conduct extensive groundwater monitoring for at least three years after the corrective measures had been fully implemented. *Id.* at 2. "The objective of the multi-year sampling program is to determine whether further review of the groundwater discharging from the site is needed and whether the overall containment is effective." *Id.* At the same time MDE noted the potential for reduction of hexavalent chromium to trivalent chromium in the natural environment – which is the basis for the current WQA. As MDE stated at that time, "[t]he natural attenuation within the Patapsco River environment, even if occurring, should not be included to serve as a component of the overall remedial strategy and serve as the de facto treatment system." *Id.* (emphasis added).[8]

The WQA fails to adequately consider the potential for continuing chromium discharges into Bear Creek and Baltimore Harbor from contaminated stormwater and groundwater at DMT. Over twenty years after the first consent decree, MDE, MPA, and Honeywell are still trying to contain the chromium pollution at DMT and prevent future discharges of hexavalent chromium-

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[7] available at http://www.mde.state.md.us/programs/Land/RecyclingandOperationsprogram/SpecialProjects/Documents/dmt%207%2030%20%2712%20letter.pdf.

[8] Note that Maryland has established numerical toxic substances criteria for trivalent chromium in fresh water (including the Northwest Branch, *see* COMAR 26.08.02.03-1) indicating that trivalent chromium can be toxic under certain circumstances and concentrations. Thus, while

laden stormwater from the site. MDE selected the storm drain relining alternative in 2012, but it will likely take several years to implement.[9] Until the implementation process is complete, DMT will likely continue to discharge significant amounts of chromium into the environment. Furthermore, years of comprehensive monitoring is required to ensure that the corrective measures will prevent future discharges of chromium laden stormwater. Until that monitoring is complete, MDE will lack sufficient data to conclude that DMT is not contributing to toxic chromium discharges into the receiving waters. Therefore, MDE should not de-list the impairments until this monitoring data has been collected, analyzed, and incorporated into an adequate water quality analysis. As MDE itself noted, potential reduction of hexavalent chromium to trivalent chromium in the environment should not be considered a treatment system for discharges from DMT.

3. **The WQA fails to adequately consider the potential for discharges from additional sources.**

As is mentioned above, the DMT is one of many sites that received COPR generated at the Baltimore Chrome Works. Many other sites throughout the Baltimore Harbor watershed contain potentially contaminated sediments. *See* MDE, Facts About Chromium Ore Processing Residue Site Initiative.[10] Until MDE investigates the other sites that potentially contain chromium contamination and studies the extent of chromium laden discharges from those sites, it will be unable to adequately determine the extent to which existing discharges are affecting Bear Creek and the Northwest Branch.

4. **The WQA fails to adequately consider the potential for conversion of trivalent chromium to hexavalent chromium through frequent dredging and storm events.**

As one of the studies relied on by the WQA clearly states, "[s]ediment oxygenation during bioturbation, flood events, and dredging activities may result in CrVI reoccurrence from

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[9] Honeywell's Storm Drain Rehabilitation Schedule for DMT, submitted to MDE on April 4, 2013, estimates that the storm drain rehabilitation work will not be completed before December 2015. *See* Attachment 1, Schedule of Implementation of Storm Drain Repairs at Dundalk Marine Terminal, Q1 2013.

[10] Available at http://www.mde.state.md.us/assets/document/Chromium%20Ore%20Processing%20Residue...

freshly precipitated $CrIII$.[11] Even if the resulting hexavalent chromium reverts to trivalent chromium within a few days or even a few hours after sediments are disturbed, aquatic organisms can still be exposed to toxic hexavalent chromium until the reversion process is complete. The Harbor area is dredged frequently to maintain Baltimore's shipping channels. The Maryland Port Administration estimates that the Port of Baltimore requires 1.5 million cubic yards of maintenance dredging each year. *See* MPA, Coke Point Risk Assessment, Frequently Asked Questions.[12] Every occurrence of dredging in the Harbor and every storm event in the Baltimore area provides an opportunity for conversion of trivalent chromium to hexavalent chromium. The WQA does not consider the frequency of these events, and the extent to which frequent sediment disturbances can cause toxic chromium conditions in the Northwest Branch and Bear Creek. MDE should not de-list these chromium impairments until the potential for toxic chromium pollution due to sediment disturbance in the Baltimore Harbor is fully understood.

5. **Re-categorizing these impairments at this time places a burden on citizen groups to collect additional water quality data.**

Given the threat of continuing discharges of chromium from DMT, Harbor Point, and other sources throughout the Baltimore Harbor, re-categorizing the chromium impairments in Bear Creek and the Northwest Branch at this time would place a significant burden on citizen groups to monitor the chromium levels in these waters. If the impairments are moved to Category 2, more data will be necessary to re-establish a basis for requiring a TMDL. While several of the studies referenced by the WQA were funded by Honeywell, citizen groups with limited resources interested in protecting the health of these waters would need to perform extensive testing near DMT, Harbor Point, and other locations. Such water quality testing is expensive; testing in a legally defensible, comprehensive and statistically meaningful manner could easily cost thousands of dollars.

Given the timing of the projects at DMT and Harbor Point and the continuing investigation of other sites, it would be far more efficient and protective of water quality to

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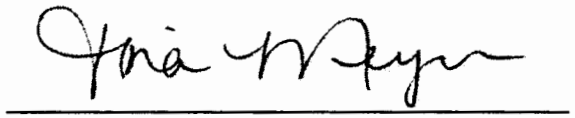
[11] *See* Amar Wadhawan, Geochemical Influences On Chromium Speciation And Fate In Estuarine Sediments; Importance Of Redox Interactions With Manganese Sulfide Minerals (2012) at 93.

[12] Available at http://www.mpa.maryland.gov/_media/client/alerts/cokepoint/faq.pdf.

2005 review of MDE's 2004 water quality analysis for these same impairments,[13] EPA allowed MDE to suspend the development of the chromium TMDL but deferred the 303(d) delisting decision until MDE conducted further studies. With active sources of chromium pollution and the possible disturbance of soils at the Chrome Works site, this is not an appropriate time to remove these impairments from the list of waters for which TMDL must be developed.

Thank you in advance for your consideration of our comments. Please let us know if you have any questions or would like to discuss further.

Sincerely,



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[13] Available at: http://www.mde.state.md.us/programs/Water/TMDL/ApprovedFinalTMDLs/Documents/www.mde.state.md.us/assets/document/chromium-inner%20harbor.pdf.

101 Columbia Road
Morristown, NJ 07962-1139
Tel: 973-455-4131
Fax: 973-455-3082

April 4, 2013

Mr. James Carroll
Administrator, Land Restoration Program
Maryland Department of the Environment
1800 Washington Boulevard, Suite 645
Baltimore, MD 21230-1719

Subject: Q1 2013 Storm Drain Rehabilitation Schedule, Dundalk Marine Terminal, Baltimore, Maryland

Dear Mr. Carroll:

Honeywell International Inc. (Honeywell) and the Maryland Port Administration (MPA) are submitting the enclosed updated "Storm Drain Rehabilitation Schedule, Dundalk Marine Terminal, Baltimore, Maryland." This update is submitted to reflect the status of remedy implementation and long-term monitoring pursuant to MDE's letter of July 30, 2012, and replaces the quarterly CMIPP update.

If you have any questions or require additional information, please contact me at 973-455-4131.

Very truly yours,

HONEYWELL INTERNATIONAL INC.

Christopher M. French
Project Coordinator

Enclosure (2 copies)

cc: Mr. Matthew Zimmerman/MDE
Mr. Mark Kreafle/MPA
Mr. Robert Munroe/MPA
Mr. Michael Daneker/Arnold & Porter

lementation of Storm Drain Repairs at Dundalk Marine Terminal, Q1 2013

Task	When Task Starts/Predecessor	Duration[a] (Calendar Days)	Status/Comments/Assumptions/Slippage Notes
rain			
truction Completion Report			
pare Draft Report	Completion of final QA/QC inspection	60–90	—
mit Draft Report to MDE	Completion of draft report	M	Scheduled for submittal to MDE by April 26, 2013
E Review and Comment Period	Submittal of draft report	TBD	Not a critical path task
ress MDE Comments	Receipt of MDE comments	30–45	Not a critical path task
mit Final Report to MDE	Response to MDE comments	10–20	Not a critical path task
rain			
truction Completion Report			
pare Draft Report	Completion of final QA/QC inspection	60–90	13.5 Street CCR preparation initiated in December 2012
mit Draft Report to MDE	Completion of draft report	M	Scheduled for Submittal to MDE by May 17, 2013
E Review and Comment Period	Submittal of draft report	TBD	Not a critical path task
ress MDE Comments	Receipt of MDE comments	30–45	Not a critical path task
mit Final Report to MDE	Response to MDE comments	10–20	Not a critical path task
rain (Planning Estimate Start Date: March 2013, Planning Estimate End Date: July 2014)			
013 Storm Rehabilitation Work			
orm condition inspections of inlets and manholes	Prior to comprehensive cleaning	30–60	Primary inspections complete
prehensive Cleaning			
elop Cleaning SOW and Procurement Documents		30	Completed during Q1 2013.
plete Solicitation and Contract Award	Completion of procurement package	30	Solicitation Complete/Bids with Contract Award during April 2013.
ractor Mobilization and Operations Clearance	Contract award	20	Mobilization to commence during May 2013.
fication to MDE of Initiation of Cleaning	Contractor mobilization	M	Cleaning to be performed on select portions of storm drains to be relined during 2013.
n Vaults, Manholes and Drain Lines	MDE notification	30–60	Cleaning will depend on extent of debris and sediment and will be performed on select portions of the vaults, manholes and drain lines to be rehabilitated during 2013.
QC Inspection of Drain	Ongoing during cleaning	30–60	Inspections to be performed during and after rehabilitation work are completed.
ractor Demobilization	Completion of final QA/QC inspection	3–10	Not a critical path task.
fication to MDE of Completion of Cleaning	Completion of final QA/QC inspection	M	Milestones task.
' and visual inspection			
are CCTV SOW and Procurement Documents	Not linked to a predecessor task	20–30	Some inspection may begin as portions of the storm drain system are cleaned.
plete Solicitation and Contract Award	Completion of procurement package.	30	—
ractor Mobilization and Operations Clearance	Contract award	10–15	—

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mentation of Storm Drain Repairs at Dundalk Marine Terminal, Q1 2013

Task	When Task Starts/Predecessor	Duration[a] (Calendar Days)	Status/Comments/Assumptions/Slippage Notes
ication to MDE of Initiation of Inspection	Contractor mobilization	M	Milestone task
ct Vaults, Manholes and Drain Lines	Completion of cleaning and MDE notification	10–20	Some inspection may occur as portions of the storm drain are cleaned
ication to MDE of Completion of Inspection	Completion of inspection	M	Milestone task
n of Rehabilitation Program			
ate Inspection Documentation	Completion of inspection	10–15	Completed during Q1 2013.
plete Selection of Rehabilitation Techniques	Completion of inspection evaluation	10–15	Completed as part of storm drain scoping during Q1 2013
are Design and Specification Documents	Selection of rehabilitation techniques	15–30	Completed during Q1 2013.
de Rehabilitation Design Documents to MDE	Completion of design	M	To be provided to MDE upon contract award during Q2 2013.
m Drain Rehabilitation			
are SOW and Procurement Documents	Completion of design	5–10	2013 SOW elements designed during Q1 2013.
plete Solicitation and Contract Award	Completion of procurement package	15–30	Completed during March 2013 for rehabilitation work to be performed during 2013.
actor Mobilization and Operations Clearance	Contract award	15–30	May 2013; schedule will depend on access to work areas based on port operations.
ication to MDE of Initiation of Rehabilitation and Update Schedule	Contractor mobilization	M	Milestone task, MDE to be provided updated schedule on contractor selection has been completed during April 2013.
bilitate Inlets and Manholes	MDE notification	200–400	Select inlets and manholes to be rehabilitated during 2013.
bilitate Storm Drain Lines	MDE notification	15–30	Select sections of storm drains to be rehabilitated during 2013.
d of Inlet and Manhole relining 2013 SOW	Contract Award	15–30	Contract award for 2013 SOW during April 2013.
QC Inspection of Drain Repairs	Ongoing during construction	10–15	Inspections to be performed during and after completion of rehabilitation activities.
ication to MDE of Completion of Repairs	Completion of final QA/QC inspection	M	Milestone task
tion of Performance Monitoring	Completion of final QA/QC inspection	M	Milestone task
ruction Completion Report			
are Draft Report	Completion of final QA/QC inspection	60–90	Not a critical path task
it Draft Report to MDE	Completion of draft report	M	Milestone task
Review and Comment Period	Submittal of draft report	TBD	Not a critical path task
ess MDE Comments	Receipt of MDE comments	30–45	Not a critical path task
it Final Report to MDE	Response to MDE comments	10–20	Not a critical path task
ain (Planning Estimate Start Date: August 2013, Planning Estimate End Date: November 2014)			
rehensive Cleaning			
op Cleaning SOW and Procurement Documents		30	14th Street line cleaning activities to be performed while construction on 15th is being completed so that 14th Street construction begins just after completion of 15th Street construction

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plementation of Storm Drain Repairs at Dundalk Marine Terminal, Q1 2013

Task	When Task Starts/Predecessor	Duration[a] (Calendar Days)	Status/Comments/Assumptions/Slippage Notes
mplete Solicitation and Contract Award	Completion of procurement package	30	—
ntractor Mobilization and Operations Clearance	Contract award	20	—
tification to MDE of Initiation of Cleaning	Contractor mobilization	M	Milestone task.
an Vaults, Manholes and Drain Lines	MDE notification	30–60	Cleaning Period will depend on extent of debris and sediment.
/QC Inspection of Drain	Ongoing during cleaning	30–60	—
ntractor Demobilization	Completion of final QA/QC inspection	3–10	Not a critical path task.
tification to MDE of Completion of Cleaning	Completion of final QA/QC inspection	M	Milestones task.
TV and visual inspection			
pare CCTV SOW and Procurement Documents	Not linked to a predecessor task	20–30	Start procurement process such that inspection can begin just after completion of cleaning. Some inspection may begin as portions of the storm drain system are cleaned.
mplete Solicitation and Contract Award	Completion of procurement package.	30	—
ntractor Mobilization and Operations Clearance	Contract award	10–15	—
tification to MDE of Initiation of Inspection	Contractor mobilization	M	Milestone task
pect Vaults, Manholes and Drain Lines	Completion of cleaning and MDE notification	10–20	Some inspection may occur as portions of the storm drain are cleaned
tification to MDE of Completion of Inspection	Completion of inspection	M	Milestone task
ign of Rehabilitation Program			
luate Inspection Documentation	Completion of inspection	10–15	—
mplete Selection of Rehabilitation Techniques	Completion of inspection evaluation	10–15	Schedule depends of extent of repairs and/or need for replacement
pare Design and Specification Documents	Selection of rehabilitation techniques	15–30	—
vide Rehabilitation Design Documents to MDE	Completion of design	M	Milestone task
orm Drain Rehabilitation			
pare SOW and Procurement Documents	Completion of design	5–10	Schedule depends on extent of repairs and/or need for replacement
mplete Solicitation and Contract Award	Completion of procurement package	15–30	—
ntractor Mobilization and Operations Clearance	Contract award	15–30	Schedule will depend on contractor readiness and port operations
tification to MDE of Initiation of Rehabilitation and Update Schedule	Contractor mobilization	M	Milestone task, provide MDE updated schedule.
abilitate Vaults, Manholes and Drain Lines	MDE notification and shortly after construction is complete at the 15th Street storm drain	200–300	Schedule depends on extent of repairs and/or need for replacement and shall initiate as soon as practical after completion of 15th Street construction.
QC Inspection of Drain Repairs	Ongoing during construction	10–15	—
ification to MDE of Completion of Repairs	Completion of final QA/QC inspection	M	Milestone task
ation of Performance Monitoring	Completion of final QA/QC inspection	M	Milestone task
struction Completion Report			
pare Draft Report	Completion of final QA/QC inspection	30–60	Not a critical path task

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nentation of Storm Drain Repairs at Dundalk Marine Terminal, Q1 2013

Task	When Task Starts/Predecessor	Duration[a] (Calendar Days)	Status/Comments/Assumptions/Slippage Notes
t Draft Report to MDE	Completion of draft report	M	Milestone task
eview and Comment Period	Submittal of draft report	TBD	Not a critical path task
ss MDE Comments	Receipt of MDE comments	30–45	Not a critical path task
t Final Report to MDE	Response to MDE comments	10–20	Not a critical path task
in (Planning Estimate Start Date: August 2014, Planning Estimate End Date: November 2015)			
ehensive Cleaning			
p Cleaning SOW and Procurement Documents		30	12th Street line cleaning activities to be performed while construction on 14th is being completed so that construction begins on 12th Street just after completion of 14th Street construction
ete Solicitation and Contract Award	Completion of procurement package	30	—
ctor Mobilization and Operations Clearance	Contract award	20	—
ation to MDE of Initiation of Cleaning	Contractor mobilization	M	Milestone task.
Vaults, Manholes and Drain Lines	MDE notification	30–60	Cleaning Period will depend on extent of debris and sediment.
C Inspection of Drain	Ongoing during cleaning	30–60	—
ctor Demobilization	Completion of final QA/QC inspection	3–10	Not a critical path task.
ation to MDE of Completion of Cleaning	Completion of final QA/QC inspection	M	Milestones task.
nd visual inspection			
e CCTV SOW and Procurement Documents	Not linked to a predecessor task	20–30	Start procurement process such that inspection can begin just after completion of cleaning. Some inspection may begin as portions of the storm drain system are cleaned.
ete Solicitation and Contract Award	Completion of procurement package.	30	—
ctor Mobilization and Operations Clearance	Contract award	10–15	—
ation to MDE of Initiation of Inspection	Contractor mobilization	M	Milestone task
t Vaults, Manholes and Drain Lines	Completion of cleaning and MDE notification	10–20	Some inspection may occur as portions of the storm drain are cleaned
ation to MDE of Completion of Inspection	Completion of inspection	M	Milestone task
of Rehabilitation Program			
te Inspection Documentation	Completion of inspection	10–15	—
ete Selection of Rehabilitation Techniques	Completion of inspection evaluation	10–15	Schedule depends of extent of repairs and/or need for replacement
e Design and Specification Documents	Selection of rehabilitation techniques	15–30	—
e Rehabilitation Design Documents to MDE	Completion of design	M	Milestone task
Drain Rehabilitation			
e SOW and Procurement Documents	Completion of design	5–10	Schedule depends on extent of repairs and/or need for replacement
ete Solicitation and Contract Award	Completion of procurement package	15–30	—
ctor Mobilization and Operations Clearance	Contract award	15–30	Schedule will depend on contractor readiness and port operations

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lementation of Storm Drain Repairs at Dundalk Marine Terminal, Q1 2013

Task	When Task Starts/Predecessor	Duration* (Calendar Days)	Status/Comments/Assumptions/Slippage Notes
ification to MDE of Initiation of Rehabilitation and Update Schedule	Contractor mobilization	M	Milestone task, provide MDE with updated schedule
abilitate Vaults, Manholes and Drain Lines	MDE notification and shortly after construction is complete at the 14th Street storm drain	200–300	Schedule depends on extent of repairs and/or need for replacement
QC Inspection of Drain Repairs	Ongoing during construction	10–15	—
ification to MDE of Completion of Repairs	Completion of final QA/QC inspection	M	Milestone task
ation of Performance Monitoring	Completion of final QA/QC inspection	M	Milestone task
struction Completion Report			
pare Draft Report	Completion of final QA/QC inspection	60–90	Not a critical path task
mit Draft Report to MDE	Completion of draft report	M	Milestone task
E Review and Comment Period	Submittal of draft report	TBD	Not a critical path task
ress MDE Comments	Receipt of MDE comments	30–45	Not a critical path task
mit Final Report to MDE	Response to MDE comments	10–20	Not a critical path task
n Drain (Planning Estimate Start Date: November 2014, Planning Estimate End Date: December 2015)			
prehensive Cleaning			
elop Cleaning SOW and Procurement Documents		30	12.5th Street line cleaning activities to be performed while construction on 12th is being completed so that construction of 12.5 Street begins just after completion of 12th Street construction
plete Solicitation and Contract Award	Completion of procurement package	30	—
tractor Mobilization and Operations Clearance	Contract award	20	—
ification to MDE of Initiation of Cleaning	Contractor mobilization	M	Milestone task.
n Vaults, Manholes and Drain Lines	MDE notification	30–60	Cleaning Period will depend on extent of debris and sediment.
QC Inspection of Drain	Ongoing during cleaning	30–60	—
tractor Demobilization	Completion of final QA/QC inspection	3–10	Not a critical path task.
fication to MDE of Completion of Cleaning	Completion of final QA/QC inspection	M	Milestones task.
V and visual inspection			
pare CCTV SOW and Procurement Documents	Not linked to a predecessor task	20–30	Start procurement process such that inspection can begin just after completion of cleaning. Some inspection may begin as portions of the storm drain system are cleaned.
plete Solicitation and Contract Award	Completion of procurement package.	30	—
tractor Mobilization and Operations Clearance	Contract award	10–15	—
fication to MDE of Initiation of Inspection	Contractor mobilization	M	Milestone task
ect Vaults, Manholes and Drain Lines	Completion of cleaning and MDE notification	10–20	Some inspection may occur as portions of the storm drain are cleaned
fication to MDE of Completion of Inspection	Completion of inspection	M	Milestone task

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mentation of Storm Drain Repairs at Dundalk Marine Terminal, Q1 2013

Task	When Task Starts/Predecessor	Duration[a] (Calendar Days)	Status/Comments/Assumptions/Slippage Notes
of Rehabilitation Program			
ete Inspection Documentation	Completion of inspection	10–15	—
lete Selection of Rehabilitation Techniques	Completion of inspection evaluation	10–15	Schedule depends of extent of repairs and/or need for replacement
re Design and Specification Documents	Selection of rehabilitation techniques	15–30	—
le Rehabilitation Design Documents to MDE	Completion of design	M	Milestone task
n Drain Rehabilitation			
re SOW and Procurement Documents	Completion of design	5–10	Schedule depends on extent of repairs and/or need for replacement
lete Solicitation and Contract Award	Completion of procurement package	15–30	—
actor Mobilization and Operations Clearance	Contract award	15–30	Schedule will depend on contractor readiness and port operations
cation to MDE of Initiation of Rehabilitation and Update Schedule	Contractor mobilization	M	Milestone task, provide MDE with updated schedule
ilitate Vaults, Manholes and Drain Lines	MDE notification and shortly after construction is complete at the 12th Street storm drain	150–250	Schedule depends on extent of repairs and/or need for replacement
C Inspection of Drain Repairs	Ongoing during construction	10–15	—
cation to MDE of Completion of Repairs	Completion of final QA/QC inspection	M	Milestone task
ion of Performance Monitoring	Completion of final QA/QC inspection	M	Milestone task
uction Completion Report			
re Draft Report	Completion of final QA/QC inspection	60–90	Not a critical path task
t Draft Report to MDE	Completion of draft report	M	Milestone task
Review and Comment Period	Submittal of draft report	TBD	Not a critical path task
ss MDE Comments	Receipt of MDE comments	30–45	Not a critical path task
t Final Report to MDE	Response to MDE comments	10–20	Not a critical path task

vary based on inspection results and severity and scope of rehabilitation.

Attach